

(NASA-TM-80102) COMPARATIVE ANALYSIS OF
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**Comparative Analysis of PA-31-350
Chieftain (N44LV) Accident
and NASA Crash Test Data**

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SUMMARY

Since 1973 the NASA Langley Research Center has conducted 20 full-scale, controlled crash tests of single-engine and twin-engine general aviation airplanes. This paper contains the results of a comparative study of an actual airplane crash (Piper PA-31-350 Chieftain (N44LV)) and the NASA crash test data. The purposes of such a comparison are to assess the NASA full-scale crash test simulations, to assess seat and floor behavior, and to estimate the acceleration levels experienced by the people killed in the crash of the Chieftain.

The study yielded four conclusions. First, the Chieftain's attitude just prior to impact was slightly pitched up, slightly rolled down to the right, and slightly yawed to the left. The airplane bounced approximately 24 m (80 ft) and probably impacted on the nose a second time slightly pitched down.

Second, the structural damage to the cabin of the Chieftain was similar to, but much greater than, that in any of the NASA tests at similar impact attitudes. This suggests that the vertical and horizontal velocities in the Chieftain crash exceeded those in the NASA controlled tests. However, the marked similarity in damage patterns between the Chieftain and the NASA test airplanes indicates that the NASA tests provide a good simulation of airplane behavior in a crash.

Third, the damage pattern to the standard passenger and crew seats of the Chieftain was similar to that in the NASA tests, but it generally showed more severe distortion indicative of a higher impact velocity.

Fourth, the peak pelvic accelerations of two passengers on the right-hand side of the Chieftain airplane probably exceeded 60g normal, 40g longitudinal, and 10g transverse.

Such crash test data as photographs, motion pictures, acceleration histories, and the tested airplanes can be correlated with and used to augment accident information to better define crash conditions and the severity of loads imposed on airplane occupants during a crash.

INTRODUCTION

The NASA Langley Research Center (LaRC) and the Federal Aviation Administration (FAA) have operated a joint program since 1973 (ref. 1) aimed at generating an understanding of structural design features which affect the crash safety of general aviation airplanes. In this program NASA has conducted 20 controlled full-scale crash tests of single-engine and twin-engine general aviation airplanes (refs. 2 to 5). Energy-absorbing fuselage structural design concepts and seat concepts are also being investigated for possible application in future aircraft designs (ref. 6).

On August 30, 1978, twin-engine Piper PA-31-350 Chieftain (N44LV), carrying nine passengers and a pilot, crash-landed in the desert shortly after taking off from the North Las Vegas Airport. All 10 persons onboard Piper PA-31-350 Chieftain (N44LV) were killed. (National Transportation Safety Board report NTSB-AAR-79-8 details the probable causes of the accident. See ref. 7.) The Chieftain crash was of particular interest because the airplane stayed essentially intact, there was no fire, and the Chieftain is similar to the standard Piper Navajos used in the LaRC tests. LaRC personnel with the assistance and cooperation of the National Transportation Safety Board (NTSB) visited the crash site to determine what could be learned relevant to the continuing crash safety program at LaRC.

This report contains the results of a comparative study of the Chieftain crash and NASA crash test data. The purposes of such a comparison are threefold: (1) assessment of the full-scale crash test simulation at LaRC; (2) assessment of seat and floor behavior; and (3) estimation of the acceleration levels experienced by the people killed in the Chieftain crash. The next three sections of the report present a brief outline of the NASA/FAA General Aviation Crash Dynamics Program, a description of the Piper PA-31-350 Chieftain crash, and a comparative study of the Chieftain crash and LaRC test data. Conclusions based on the field experience and study are also presented.

Values are given in both SI and U.S. Customary Units. The measurements and calculations were made in U.S. Customary Units.

NASA/FAA GENERAL-AVIATION CRASH DYNAMICS PROGRAM

In August of 1972, Hurricane Agnes caused extensive flooding in the mountainous regions of Pennsylvania. The Piper Aircraft Corporation plant in Lock Haven, Pa., was one of many flooding victims of the Susquehanna River. Completed airplanes parked outside the plant, as well as many in various stages of construction, were flooded and rendered essentially unflightworthy. The NASA Langley Research Center was fortunate, through the cooperation of Piper Aircraft Corporation and the FAA, to obtain 32 Navajo, Aztec, and Cherokee airplanes in various stages of completion.

The idea of a research program for improving general aviation safety had already germinated at LaRC when these Piper airplanes became available. A large gantry called the Langley lunar landing facility, built in the early 1960's to simulate lunar excursion module landings on the moon, was available for conversion to an aircraft crash testing facility. With some relatively inexpensive modifications, the structure was changed to a swing framework for full-scale crash testing of aircraft under 13 600 kg (30 000 lb) gross weight. The testing facility is now the Langley impact dynamics research facility (ref. 2). The testing technique has the unique feature of full release of the aircraft just prior to impact, simulating three-dimensional free-flight crash conditions.

To date, standard Navajos (refs. 3 to 5), pressurized Navajos, Cherokees, Cessna 172's (ref. 8), and Boeing-Vertol CH-47 helicopters (refs. 9 and 10) have been crash-tested in the Langley impact dynamics research facility. Of all the tests conducted, the ones pertinent to this study are listed in table I together

with the actual measured impact parameters. Tests 1 to 10 and test 16 used the standard Navajo; tests 14 and 15 used the pressurized version of the Navajo. Impact parameters have been varied to give nose-down impacts at 15°, 30°, and 45° with negligible angle of attack, roll, and yaw; flat and tail-down impacts at nominal 15° flight-path angle; and nose-down impacts with 15° and 30° roll at 15° flight-path angle. In these tests the flight-path velocity varied from 13 to 41 m/s (25 to 80 knots). The variety of flight-path angles in relation to the impact surface produced vertical impact velocities of 4 to 21 m/s (7 to 41 knots) and horizontal impact velocities of 12 to 39 m/s (24 to 76 knots). Instrumentation onboard the airplane test specimens consisted of accelerometers, strain gages, load cells, and high-speed movie cameras. Time histories of accelerations, strain, and load were recorded during the simulated airplane crashes.

All of the twin-engine airplanes crash-tested in the program at LaRC have impacted on a concrete pad representing a hard runway. Two single-engine airplane tests have used a 1.2-m- (4-ft-) thick dirt impact surface approximating a soft field.

CHIEFTAIN CRASH

The Piper PA-31-350 Chieftain is a stretched 8- to 10-place twin-engine airplane with counterrotating 350-hp (1 hp = 746 W) engines. Figure 1 is a photograph of a 1978 Chieftain which differs only slightly from the one that crashed. The Chieftain in the photograph does not have a pilot's door as did the airplane which crashed. The Chieftain has a gross weight limit of 3200 kg (7000 lb) and a stall speed of 38 m/s (74 knots).

The crashed airplane was a PA-31-350 Chieftain with commuter-seat configuration for eight passengers and two crew members as shown in figures 2(a) and 2(b). The first row of passengers behind the crew seats sat in legless seats mounted on tracks directly over the main spar and evaporator units of the air-conditioning system. The next two rows of passengers sat in standard Navajo passenger seats (Chieftain seats are the same as those onboard the standard Navajo). The passengers in the rear sat in two special seats both adapted to straddle a step in the floor (fig. 2(b)). The seat on the left had short legs in front with none in the rear. The seat on the right was the toilet seat. It also had no rear legs, but had a front leg arrangement formed of sheet metal. All seats faced forward. All seats, except the two rear ones, were attached to tracks. The left rear seat was attached to the floor with detachable anchor pins which fit into floor-mounted plates. The right rear seat also had the detachable anchor pin/plate arrangement for rear attachment, but the front leg was formed of sheet metal and was attached to the floor with two bolts.

There were more than 20 eyewitnesses to this crash. The composite description of the accident is that the airplane's attitude during climbout was high; the airplane reached an altitude in excess of 61 m (200 ft); the airplane rolled to the right, pitching steeply downward; the airplane descended toward the ground at a very steep angle with the nose down; and at impact the airplane's attitude was nearly level with the ground. The Chieftain bounced upon impact and traveled approximately 24 m (80 ft) through the air before impacting again,

coming to rest about 27 m (90 ft) from the initial impact point. The impact terrain was nearly level desert with sparse, scrubby brush. The soil was loose and very fine near the surface, but quite firm after a depth of approximately 1 1/2 cm (6 in.). The impact changed the compaction of the soil from a California bearing ratio (CBR) value of 23 to one of 9 at the initial impact site.

A frontal view of the wreckage is shown in figure 3. The external damage included loss of wing dihedral angle, left wing tip broken downward, failed engine mounts, and undercrushing of the nose and cockpit with skin separation on both sides below the windshields. In addition, the right side window line was severely distorted with the escape hatch missing and escape hatch frame skewed. There were splits in the roof at the rear frame of the escape hatch, between the copilot window and the next rearward window, and also below the copilot window. The tail cone was broken down with a large separation at the forward frame of the rear door; a huge outward bulge occurred in the lower right rear side behind the wing; the cabin roof was wrinkled evidencing cave-in. The left side of the cabin fuselage is relatively undamaged, and the empennage also remained relatively undamaged.

The structural damage, the initial impact impressions, the interior seat and floor damage (discussed later), and the eyewitness accounts, all point to the following crash sequence: the airplane had a steep angle of descent and an attitude slightly rolled down to the right, slightly yawed to the left, and slightly pitched up just before impact; the initial contact was made by the lower fuselage on the right side opposite the rear cabin door; an instant later the rest of the fuselage impacted on its lower right side along with the level right wing; the left wing subsequently slapped down breaking the tip; the airplane then became airborne again, traveling approximately 24 m (80 ft) before it impacted again slightly nose down, and slid approximately 3 m (10 ft).

The interior measurements of the cabin taken at the main spar (fig. 4) indicate a 13-cm (5-in.) lateral expansion and an 18-cm (7-in.) drop in the ceiling. The actual changes of dimensions during the impact were probably substantially greater than the measured final dimensions. During the nose-down impact of the NASA test 7 specimen, the entire cockpit roof folded and caved in, only to unfold instants later.

The weights and seat locations of the occupants are shown in figure 5. Seats 1 to 8 stayed in place, and the lap belts retained the passengers. Seats 9 and 10 broke free of the floor. The passenger of seat 9 was thrown forward, coming to rest in the aisle between the crew seats and first row of passengers. Since passenger 9 was thrown forward and the lap belts were uncut, he was probably not wearing the lap belt. Passenger 10 was found in the rear of the cabin with the seat back broken to the rear under the upper torso. After the crash, all lap belt buckle mechanisms were found to be operational.

COMPARATIVE ANALYSIS OF N44LV CHIEFTAIN CRASH DATA AND NASA TEST DATA

Exterior Damage

The damage to the nose of the Chieftain (fig. 6(a)) resembles that of the NASA test 8 specimen (fig. 6(b)), a nose-down impact. The 0.6-m (2-ft) exten-

sion of the Chieftain's fuselage is evident in the comparison of these two photographs. The deep side crease of the nose is probably a good indication that the second impact was nose-down.

A left-side view of the Chieftain is shown in figure 7(a). This view shows the tail-cone breakdown, roof depression, and broken wing tip. The NASA test 10 specimen of figure 7(b) is typical of tail-cone breakdown in the NASA tests.

The right-side view of the Chieftain as shown in figure 8(a) shows the extensive damage to the right side of the fuselage with little damage to the wing. This side-fuselage damage is more severe than any of the NASA test airplanes have exhibited. Figures 8(b) and 8(c) show the NASA test 4 airplane, a nearly flat impact, and the test 2 airplane, a low-angle nose-down impact. These two specimens show some cabin roof depression and slight skewing of the escape hatch frame.

The tail-cone separation and bulge in the Chieftain's fuselage are shown in figure 9(a). Corresponding views showing tail-cone breakdowns in NASA tests 3 and 10 are shown in figures 9(b) and 9(c). The NASA test 4 specimen (fig. 9(d)) contacted the impact surface slightly pitched up. The damage is obviously in the same location as the Chieftain's bulge. Similarly, the NASA test 6 specimen, a tail-down impact (fig. 9(e)) shows similar damage. This specimen impacted along the tail undersurface, pitched up at a nominal 15°. The Chieftain's bulge indicated the initial contact point along the underbelly.

Figures 10(a), 10(b), and 10(c) show the upper separation of the tail cone of the Chieftain and comparable separations in specimens from NASA tests 10 and 3.

Interior Floor Damage

Figure 11 shows the Chieftain's cockpit floor area after removal of the seats. The sheet metal has been removed so that damage to the control tunnel can be seen. There was significant reduction of the vertical clearance between the instrument panel and the floor (approximately 25 cm (10 in.), or better than 40 percent). Similar control-tunnel damage can be seen in figure 12 which shows the NASA test 8 specimen, a nose-down impact.

Figures 13(a) and 13(b) show the waviness of the cabin floor, broken floor seat rails, crumpled substructure, and distortion of the right side of the cabin fuselage. These photographs show that the floor was most severely crushed under the front legs of the seats. None of the NASA test specimens has experienced such severe cabin floor damage. NASA tests 7 and 15 show similar trends, but much less damage. The NASA test 7 specimen had floor deformations under the first passenger seat (figs. 13(c) and 13(d) with the floor uncovered). The NASA test 15 specimen in figure 13(e) had the same pattern of overall waviness.

The rear cabin floor of the Chieftain (fig. 14(a)) shows a depressed floor area at the forward seat leg and passenger feet locations. The forward fuselage frame at the door was completely broken below the floor on the left side. The vertical step in the floor was deformed to about 45°. The view through the rear

door of the NASA test 4 specimen which sustained a nearly level impact, shows considerable upheaval (fig. 14(b)). There were no simulated passengers in this area and the floor was not covered with sheet metal. This was the initial contact area for the NASA test 4 specimen and probably for the Chieftain. The differences in appearance are probably due to the lack of seats and dummies and sheet-metal covering in NASA test 4.

Seat Damage

Both seats 1 (pilot) and 2 (copilot), as shown in figure 15(a), stayed firmly clamped to the floor rails. The rear vertical frames were bent forward approximately 30°. There was severe bending and fracturing of the side diagonal support tubes where they attach to the rear vertical frame. The seat cushions were folded downward in the center with the side frame members bent downward. The undertubing supporting the seat frames was also buckled. Similar damage has been seen in the NASA tests. Two pilot seats from NASA test 7 (fig. 15(b)) and NASA test 8 (fig. 15(c)), both of which were nose-down impacts, show bending and fracturing of the side diagonal support tubes.

Passenger seats 3 and 4 (fig. 16(a)) were legless and sat over the main spar and air-conditioning evaporator units. These seats remained firmly clamped to the rails; however, they were tilted forward and downward as a result of collapse of the sheet-metal housing over the spar and evaporator units and the forward rotation of the spar (fig. 16(b)). Both seat pans (rubber diaphragm) were torn, and the seat frame of seat 3 was skewed. None of the NASA tests included this seat.

Seats 5 to 8 were standard passenger seats of the type shown in figure 17 with a Hybrid II anthropomorphic dummy used in the NASA tests. The seat leg and frame arrangement can easily be seen in the photograph.

Figure 18 shows that seat 5 was severely distorted forward, downward, and to the right. Only the right rear clamp remained attached; however, the sheet-metal leg nearly tore free above the clamp. The left floor rail fractured in three places - at both the front and the rear leg attachment points and in between. The right rail was also fractured at the right front leg attachment point.

Only the left front attachment clamp of seat 6 (fig. 19) came free of the rail. The seat legs collapsed in front, and the seat generally deformed to the right and down. This seat is discussed more fully later in the report. The floor rail had very sharp bends at the front leg attachment points.

Seats 7 and 8 are shown in figure 20(a). The right front and left rear leg attachments of seat 7 were separated from the rail. The seat legs collapsed in front, and the seat generally deformed to the right and down. The left floor rail was partially fractured at the front leg attachment point, and the right floor rail was completely fractured at a point between the leg attachment points.

Seat 8 exhibits more forward distortion than seat 7 with less distortion to the right, probably because of the side fuselage. Only the right rear clamp stayed attached to the floor rail. The sheet metal of this leg tore above the clamp when the leg bent forward. The floor rail was fractured at both front leg attachment points. This seat is also studied in more detail later in this report. The rear member of the seat frame was bent downward and completely separated on the left side. Figure 20(b) shows similar, but less severe, damage to the first passenger seat of the NASA test 7 airplane.

Passenger seat 9, shown removed from the airplane in figure 21, came loose during the crash. The front legs completely buckled under the seat and to the left. The seat frame was severely distorted with the rear member torn and bent downward and the right rear frame connection pulled apart. The floor tiedown plates exhibit damage from the pins which were pulled out. NASA has not had a similar seat on any of its tests.

Passenger seat 10, the toilet seat, was crushed almost completely flat (fig. 22). The front legs were not separate legs, but a formed piece of sheet metal. Bolts held the seat to the front tiedown plates with pins fitting into rear tiedown plates. The front sheet-metal leg was flattened forward and torn free of the seat. None of the NASA tests involved a similar seat.

Figures 23(a) and 23(b) compare frontal views of seats 6 and 8 from the Chieftain with seat 3 from NASA test 15. The NASA test 15 specimen was a pressurized Navajo that impacted, rolled down to the left with the left wing nearly level, which caused the seat deformation to be opposite that of the Chieftain's. The weights of the occupants of seats 6 and 8 (71.7 and 75.3 kg (158 and 166 lb), respectively) were nearly the same as the weight of the dummy (74.8 kg (165 lb)) used in NASA test 15. Although the gross characteristics of the damage are the same, the damage is more severe in the accident case. The dummy in the NASA test went down through the seat. In addition, the rear member of the seat frame was bent downward and was almost completely separated on the right side. A similar failure occurred on the opposite side of Chieftain seat 8.

Figure 24 contains the smoothed acceleration histories of the pelvis of the first passenger dummy from NASA test 15 along with the normal acceleration of the floor near the right front leg of the seat. The dummy pelvis experienced peaks of -62g normal (along the spine), 40g longitudinal (forward), and -15g transverse (right sideward) with a pulse duration of approximately 0.06 sec. ($1g = 9.8 \text{ m/sec}^2$.) The normal acceleration peak at the floor near the right front leg of the seat was -105g with a pulse duration of approximately 0.04 sec. Table II gives a synopsis of the pertinent passenger seat acceleration data from all the NASA tests. The tests listed as section 1 and section 2 (ref. 11) were vertical drop tests of standard Navajo fuselage sections 1.5 m (5 ft) long. The tests were designed to produce a vertical impact pulse into the subfloor, seats, and dummies of the first row of passengers behind the crew.

The comparison of seat damage indicates that the passengers of seats 6 and 8 of the Chieftain probably experienced pelvic accelerations in excess of those measured on the first passenger of NASA test 15.

CONCLUSIONS

After a complete review of the data from the NASA/FAA General Aviation Crash Dynamics Program and comparison with the information on the crash of the Piper PA-31-350 Chieftain, the following comparative conclusions are made based on experience and judgment:

1. The Chieftain's attitude just prior to impact was slightly pitched up, slightly rolled down to the right, and slightly yawed to the left. The airplane initially contacted the nearly level terrain at a location along the lower fuselage on the right side opposite the rear door. An instant later the rest of the fuselage and the level right wing impacted the terrain. The airplane bounced approximately 24 m (80 ft) and probably impacted on the nose a second time slightly pitched down. The airplane came to rest approximately 27 m (90 ft) from the initial impact point.

2. The structural damage to the cabin of the Chieftain was similar to, but much greater than, that to airplanes in any of the NASA tests at similar impact attitudes. This suggests that the vertical and horizontal velocities in the Chieftain crash exceeded the 21 m/s (41 knots) and 39 m/s (76 knots) maximum vertical and horizontal velocities, respectively, in the NASA controlled tests. The marked similarity between the structural deformations observed on the crashed Chieftain and those observed on similar airplanes crashed under controlled conditions at the Langley Research Center indicates that a good simulation of actual crash conditions is being achieved in the crash tests.

3. The pattern of damage to the standard passenger and crew seats of the Navajo Chieftain was similar to that in the NASA tests, but generally showed more severe distortion indicative of a higher velocity impact.

4. The peak pelvic accelerations of passengers 6 and 8 were probably in excess of 60g normal, 40g longitudinal, and 10g transverse. This conclusion is based on a direct comparison between damage observed on seats 6 and 8 of the Chieftain and seat 3 of the airplane in NASA test 15.

Crash test data such as photographs, motion pictures, acceleration histories, and tested airplanes can be correlated with and be used to augment actual accident information to better define crash conditions and the severity of loads imposed on the occupants of an airplane during a crash.

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TABLE I.- IMPACT PARAMETER DATA FROM TESTS IN NASA/F2A

GENERAL AVIATION CRASH DYNAMICS PROGRAM

Test (a)	Parameter									
	Flight-path angle, deg	Angle of attack, deg	Pitch angle, deg	Roll angle, deg	Yaw angle, deg	Velocity, ft/s (knots)				
						Flight path	Vertical	Horizontal		
1	-16.75	1.00	-15.75	0.00	0.00	12.66 (24.61)	3.65 (7.10)	12.13 (23.58)		
2	-16.00	4.00	-12.00	.00	1.50	25.66 (51.83)	7.35 (14.3)	25.63 (49.83)		
3	-18.75	.75	-18.00	1.25	.50	26.19 (50.91)	8.42 (16.4)	24.80 (48.21)		
4	-14.75	19.00	4.25	.00	-.50	27.38 (53.23)	6.97 (13.5)	26.47 (51.46)		
5	-20.50	1.00	-19.50	3.75	3.25	26.10 (50.74)	9.14 (17.8)	24.45 (47.53)		
6	-16.50	30.50	14.00	.50	.00	26.86 (52.22)	7.63 (14.8)	25.76 (50.08)		
7	-47.50	.25	-47.25	.00	2.50	28.60 (55.60)	21.09 (41.00)	19.32 (37.56)		
8	-30.0	1.2	-31.2	-1.0	2.0	27.6 (53.7)	13.8 (26.8)	23.9 (46.5)		
9	-16	3	-13	-30	14	26.3 (51.1)	7.3 (14)	25.3 (49.2)		
10	-18	4	-14	-15	8	27.8 (54.0)	8.6 (17)	26.4 (51.3)		
b14	-16.75	5.0	-11.75	.75	2.0	32.69 (63.55)	9.46 (18.4)	31.43 (61.10)		
b15	-18	6.00	-12.0	-6.0	-5.0	41.4 (80.5)	12.7 (24.7)	39.3 (76.4)		
b16	-16.0	11.0	-5.0	5.0	11.5	27.5 (53.5)	7.59 (14.7)	26.5 (51.4)		

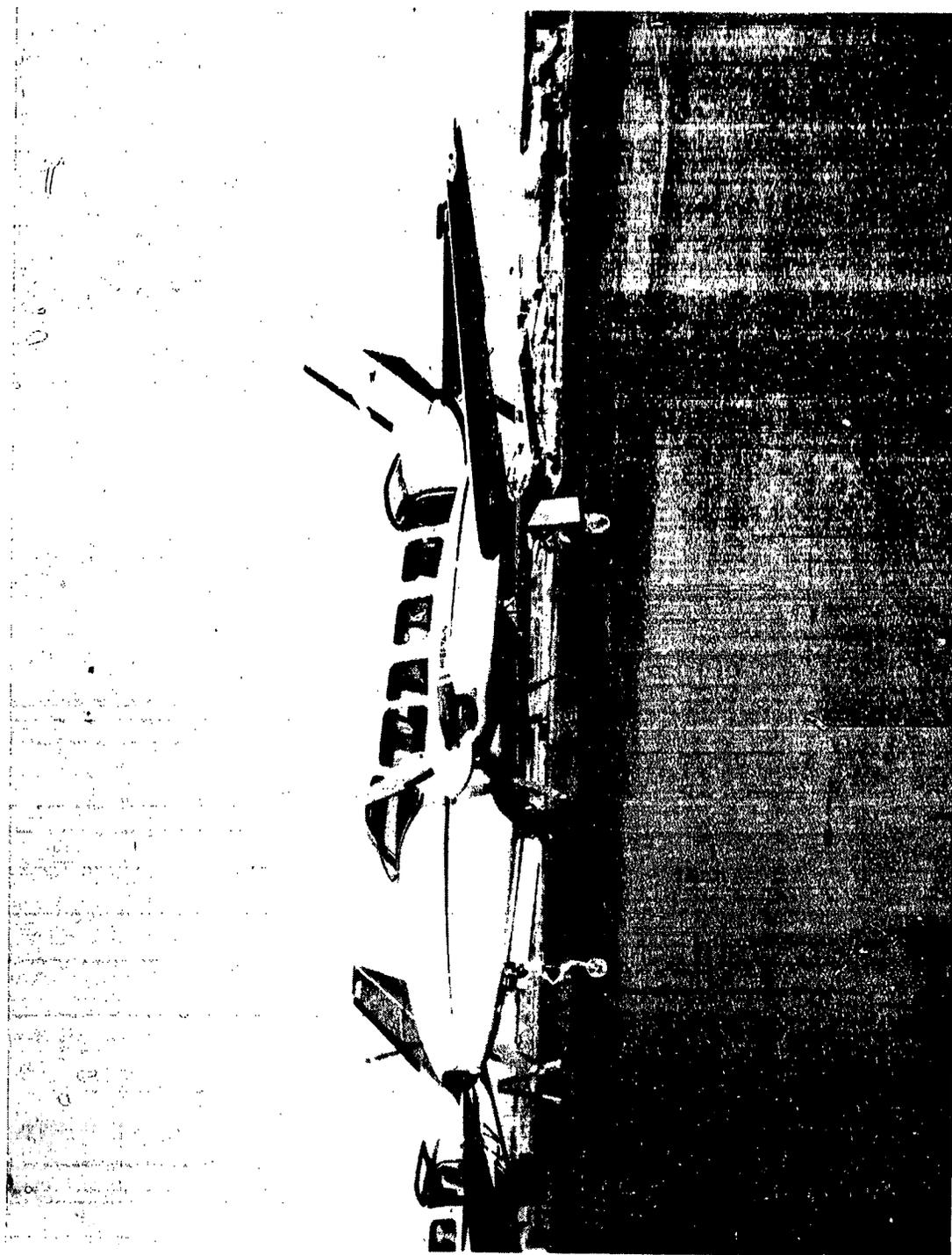
^aTests 1 to 10 and 16, standard Navajo; tests 14 and 15, pressurized Navajo.

^bRocket augmented.

TABLE II.- PELVIC ACCELEROMETER DATA AND SEAT DAMAGE FROM NASA TESTS

NASA test	Seat location (a)	Restraint		Peak acceleration, g units	Pulse duration, sec	Seat damage
		Lap	Chest			
15 nose impact	First passenger	X	X	-62 normal 40 longitudinal -15 transverse	0.063 .056 .050	Gross deformation of seat frame and legs. Dummy went down through seat pan.
	(b)					
16 nose impact	First passenger	X	X	-42 normal 20 longitudinal -21 transverse	0.060 .040 .014	Gross deformation of seat frame and legs. Dummy went down through seat pan.
	Second passenger	X		-65 normal 32 longitudinal -15 transverse	0.042 .044 .030	
Section 1	First passenger	X	X	-45 normal	0.040	Moderate damage. Rear seat frame member bent and twisted.
Section 2	First passenger	X	X	-45 normal	0.045	Moderate damage. Rear seat frame member bent and twisted.
	Second passenger	X	X	-46 normal	0.045	Moderate damage. Rear seat frame member bent and twisted. Side cross-brace member began buckling.

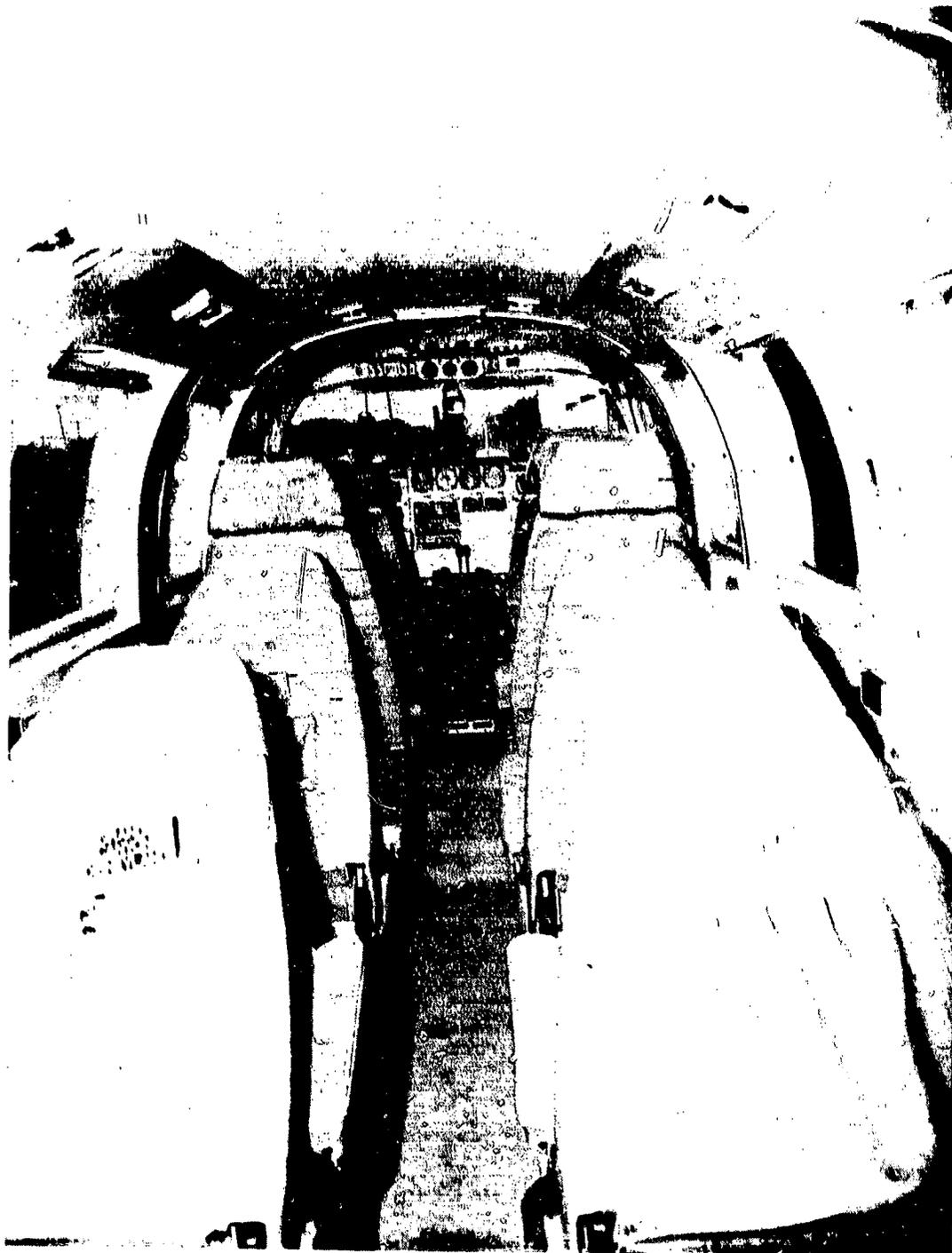
^aAll seats were standard Navajo passenger seats.
^bAll occupants were 74.8-kg (165-lb) Hybrid II dummies.



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Figure 1.- 1978 Piper Chieftain.

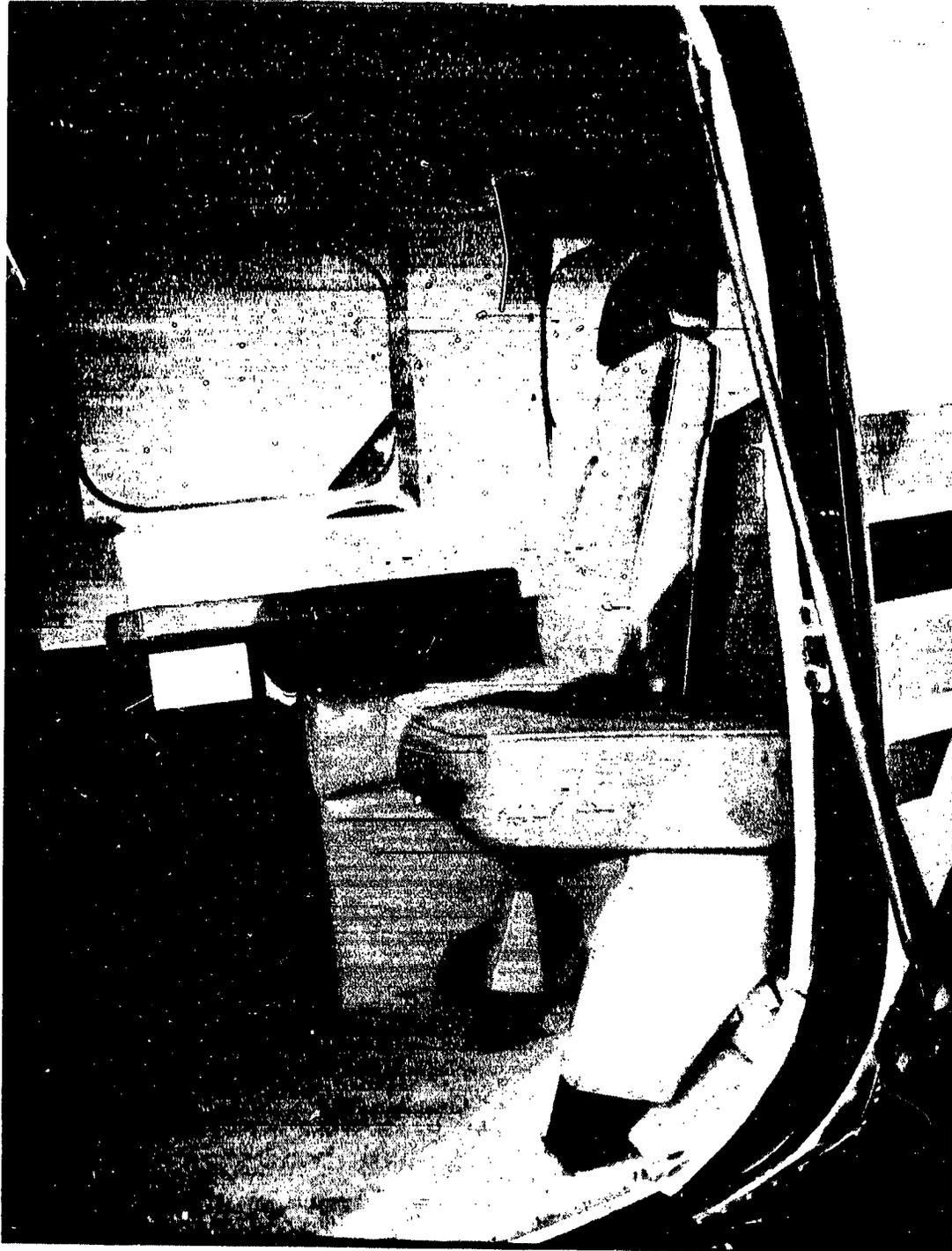
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(a) View from rear.

Figure 2.- Interior of C-119A Gristle.



(b) Rear seats.

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Figure 2.- Concluded.



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Figure 3.- Front view of Piper (PA-31-350) Chieftain (N44LV) which crashed August 30, 1978, after take-off from North Las Vegas Airport.

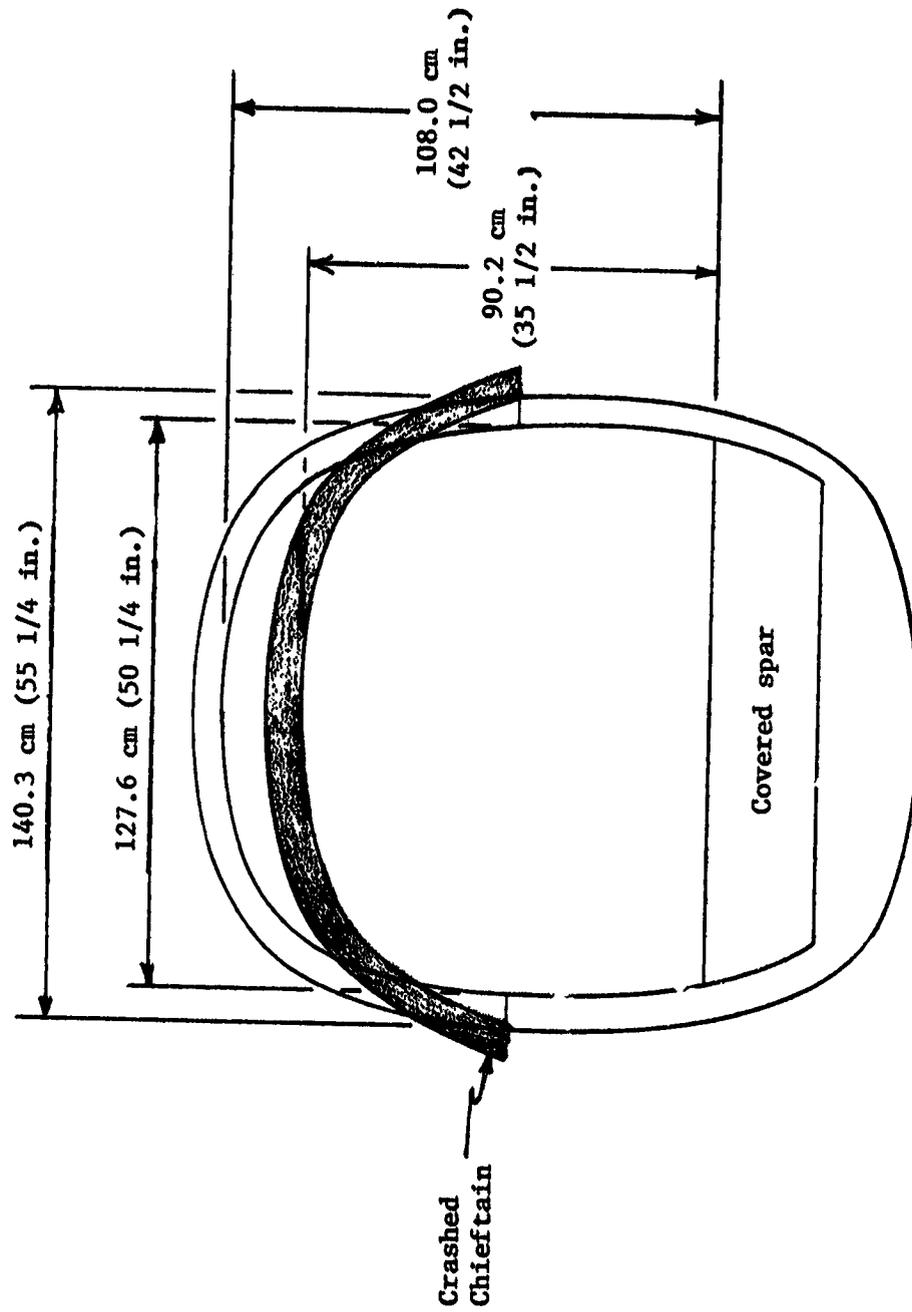


Figure 4.- Fuselage cross-section distortion above covered main spar.

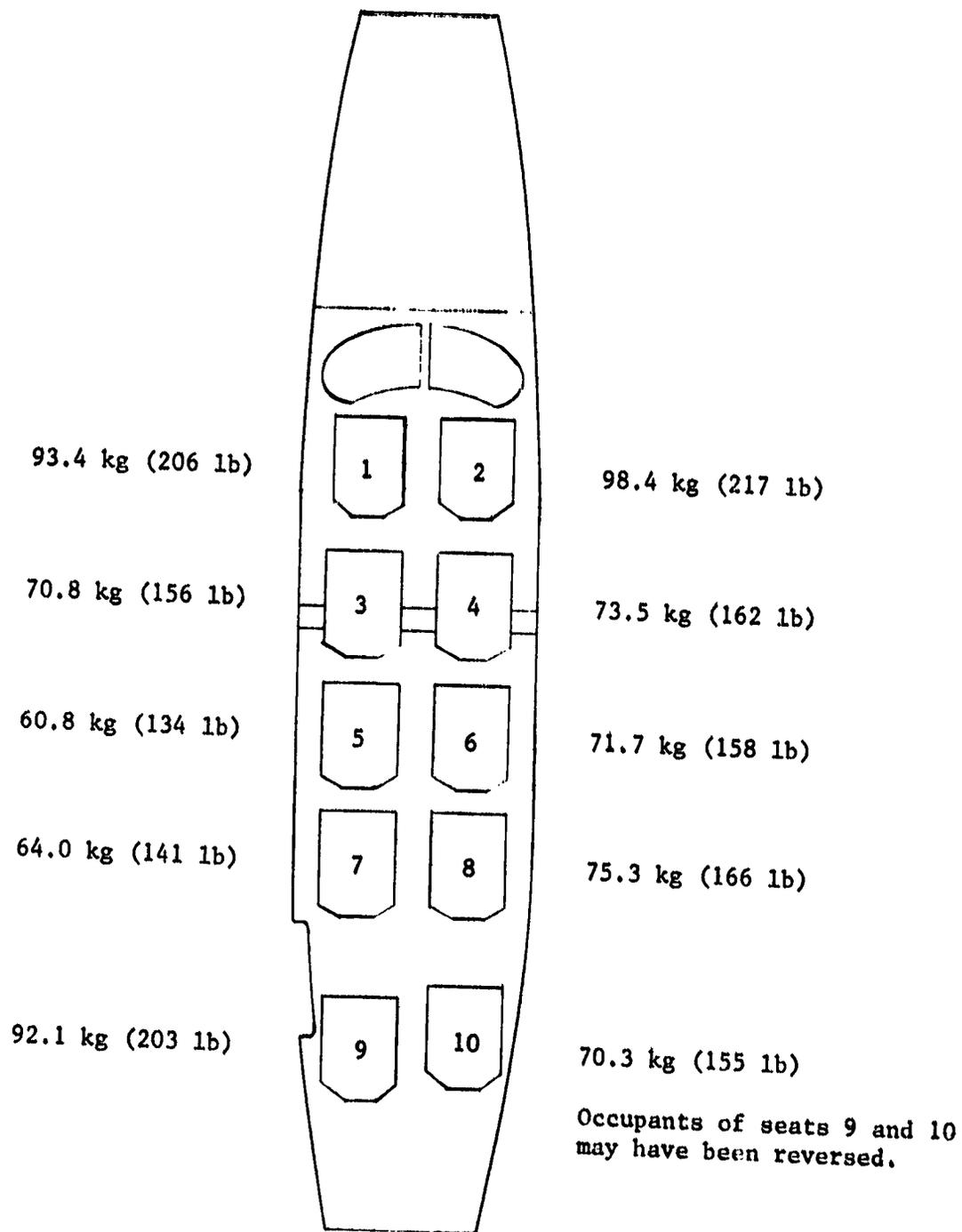


Figure 5.- Weights and locations of Navajo Chieftain occupants.



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(a) Chieftain.

Figure 6.- Frontal damage to crashed airplanes.



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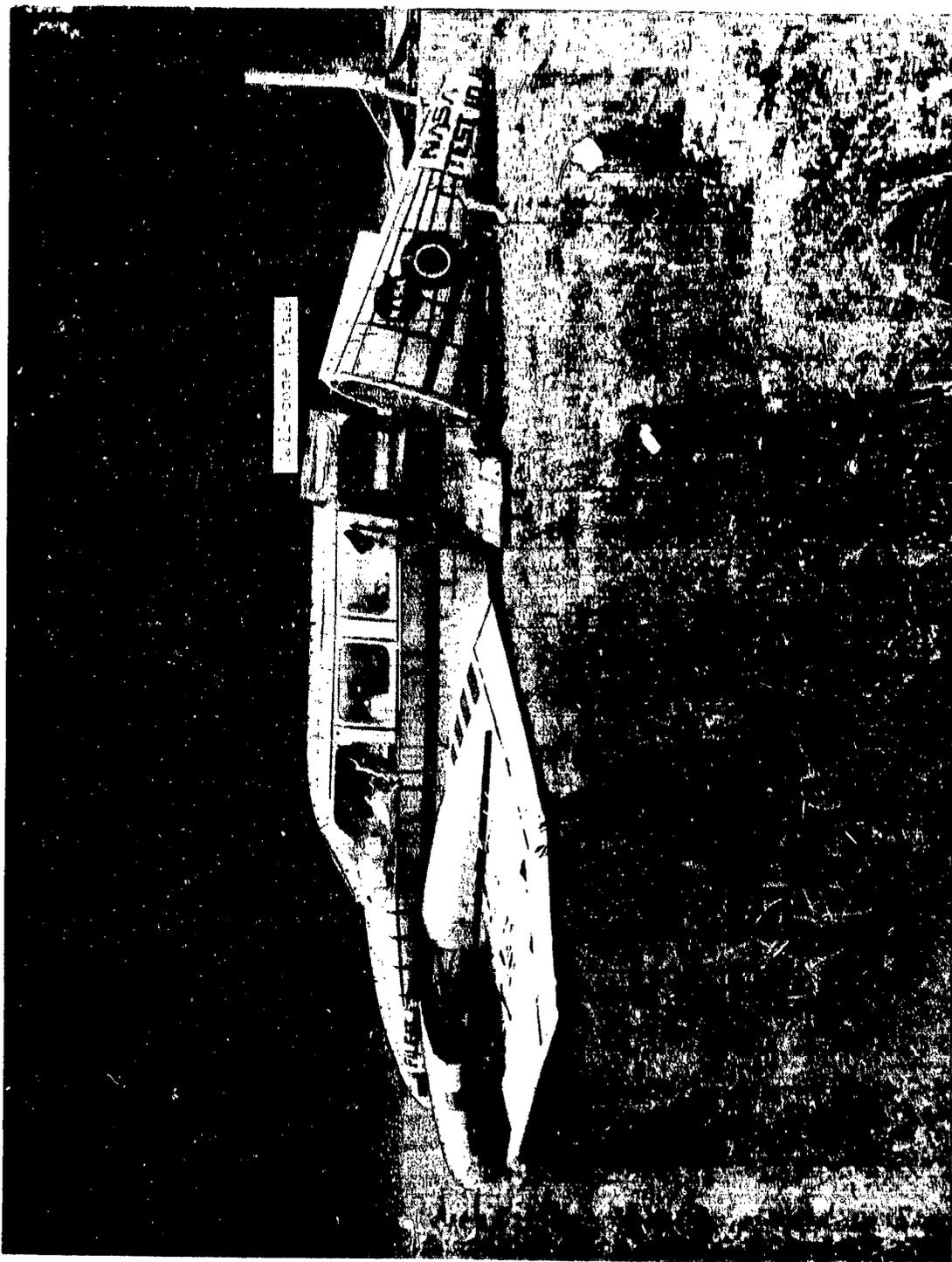
(b) NASA test 8 standard Navajo.

Figure 6.- Concluded.



(a) Chieftain.

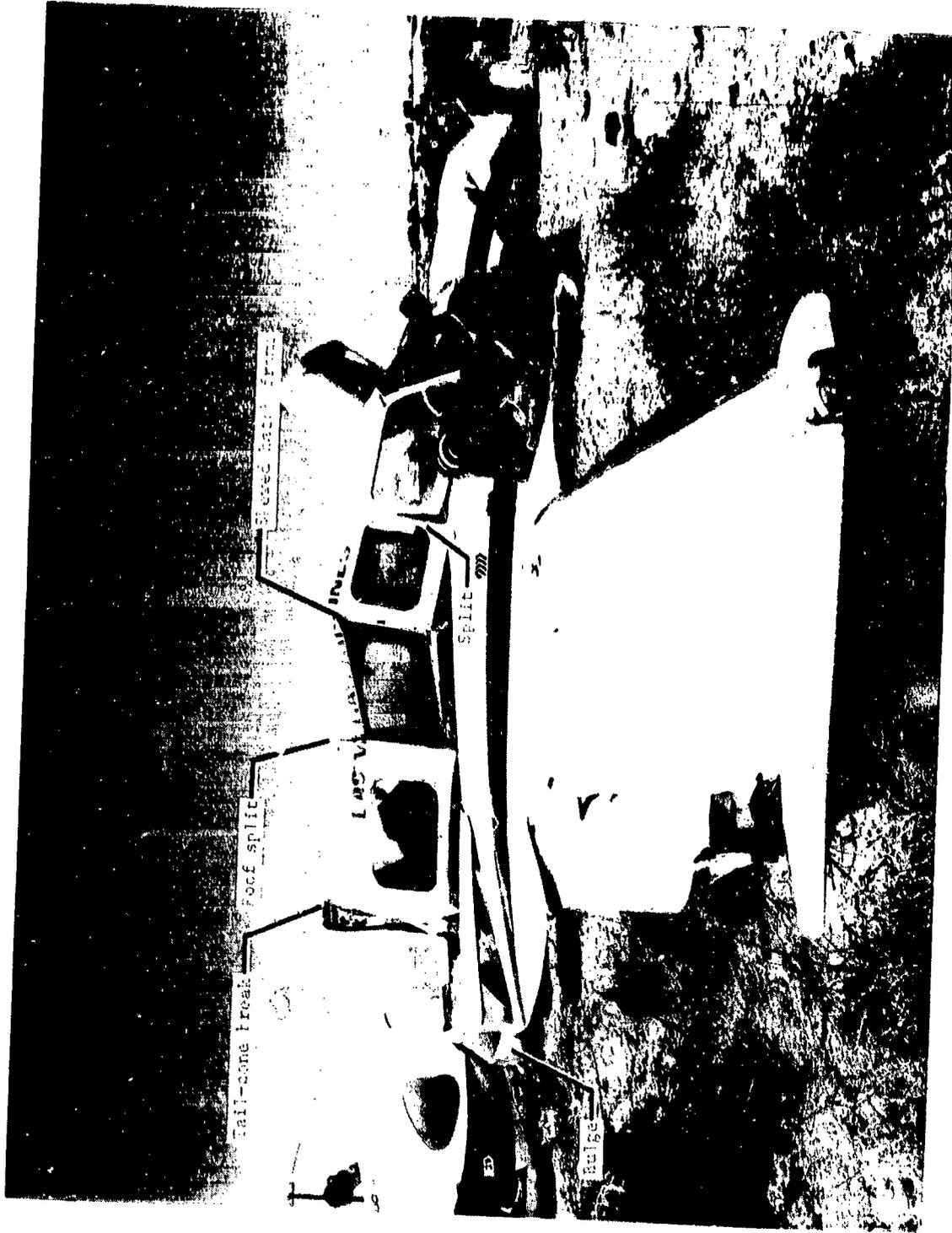
Figure 7.- View of left side of crashed airplanes.



L-76-4734.7

(b) NASA test 10 standard Navajo.

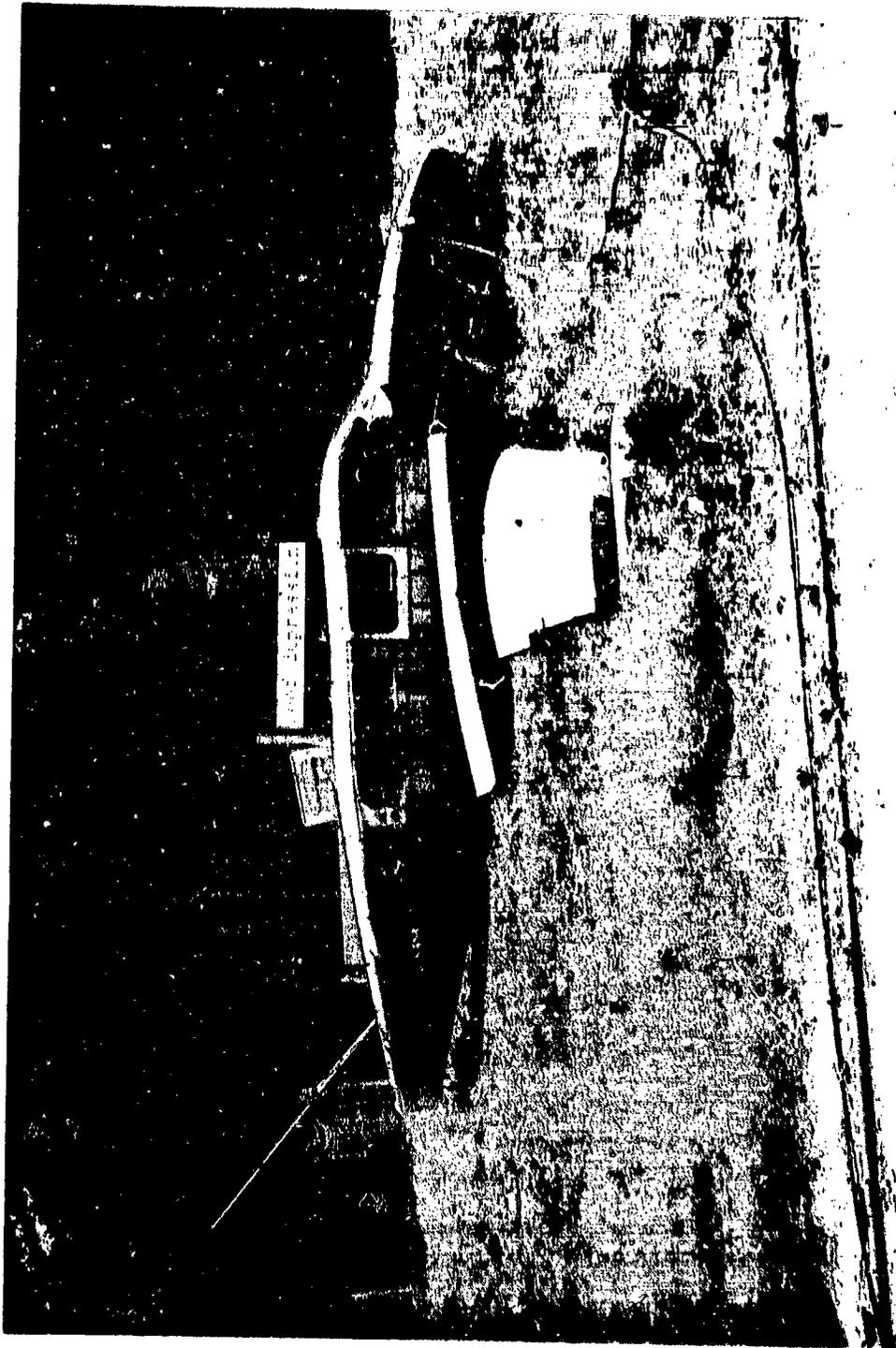
Figure 7.- Concluded.



I-78-6750.7

(a) Chieftain.

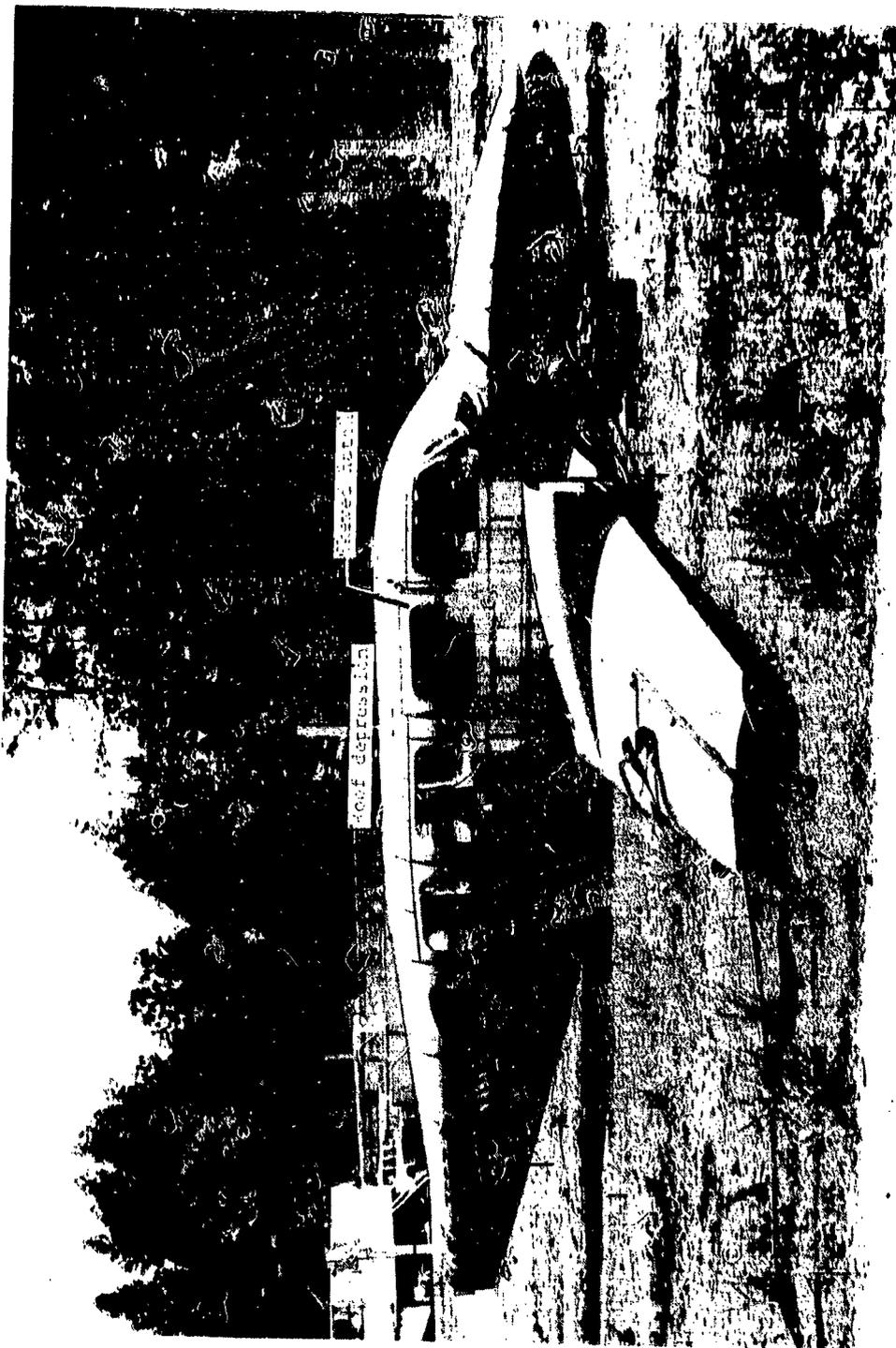
Figure 8.- View of right side of crashed airplanes.



L-74-8057.7

(b) NASA test 4 standard Navajo.

Figure 8.- Continued.



L-74-2623.7

(c) NASA test 2 standard Navajo.

Figure 8.- Concluded.



IL-78-6764.7

(a) Chieftain.

Figure 9.- Right rear quarter view of crashed airplanes.

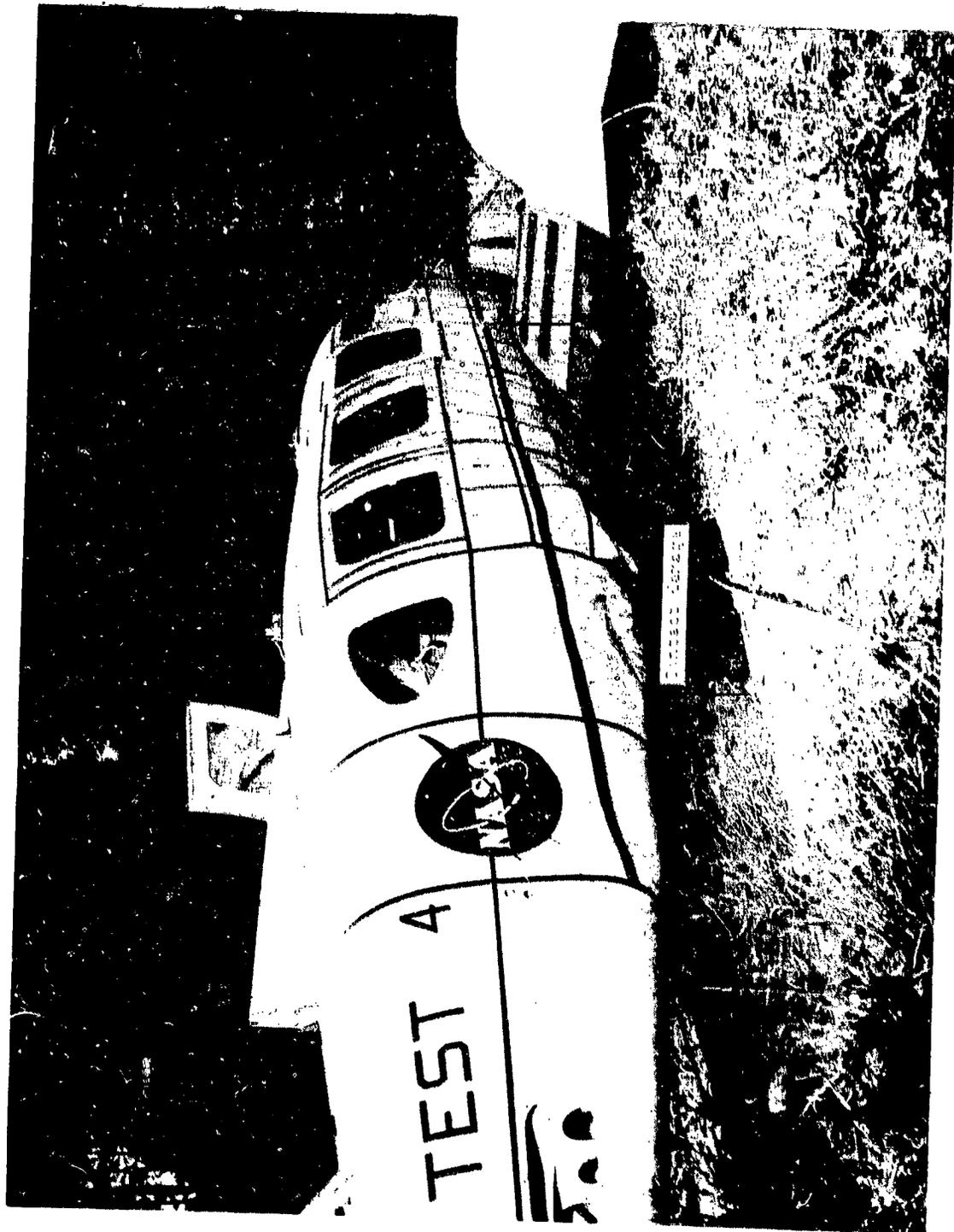
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L-76-4732.7

(c) NASA test 10 standard Navajo.

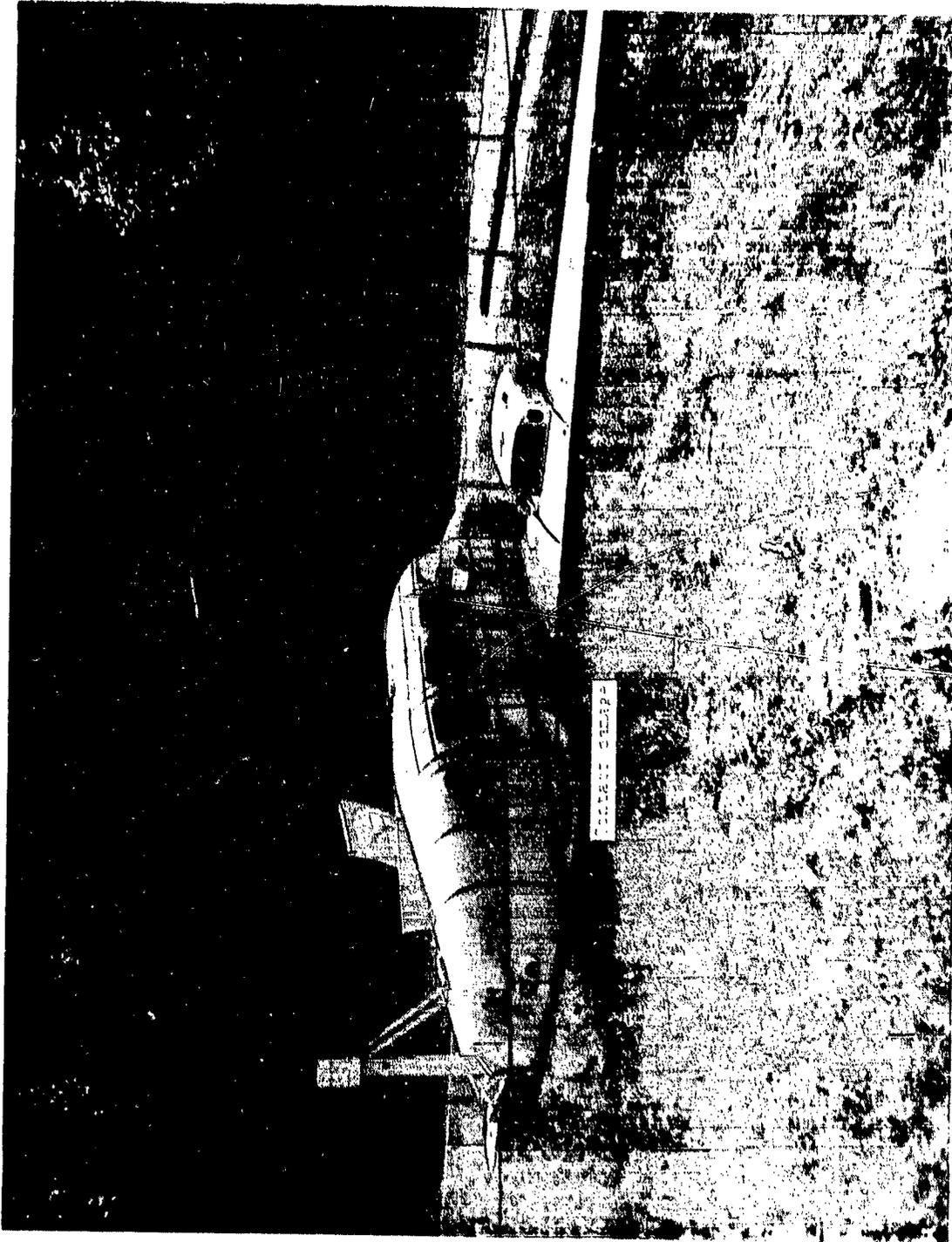
Figure 9.- Continued.



L-74-9087

(d) NASA test 4 standard Navajo.

Figure 9.- Continued.



L-75-3747.1

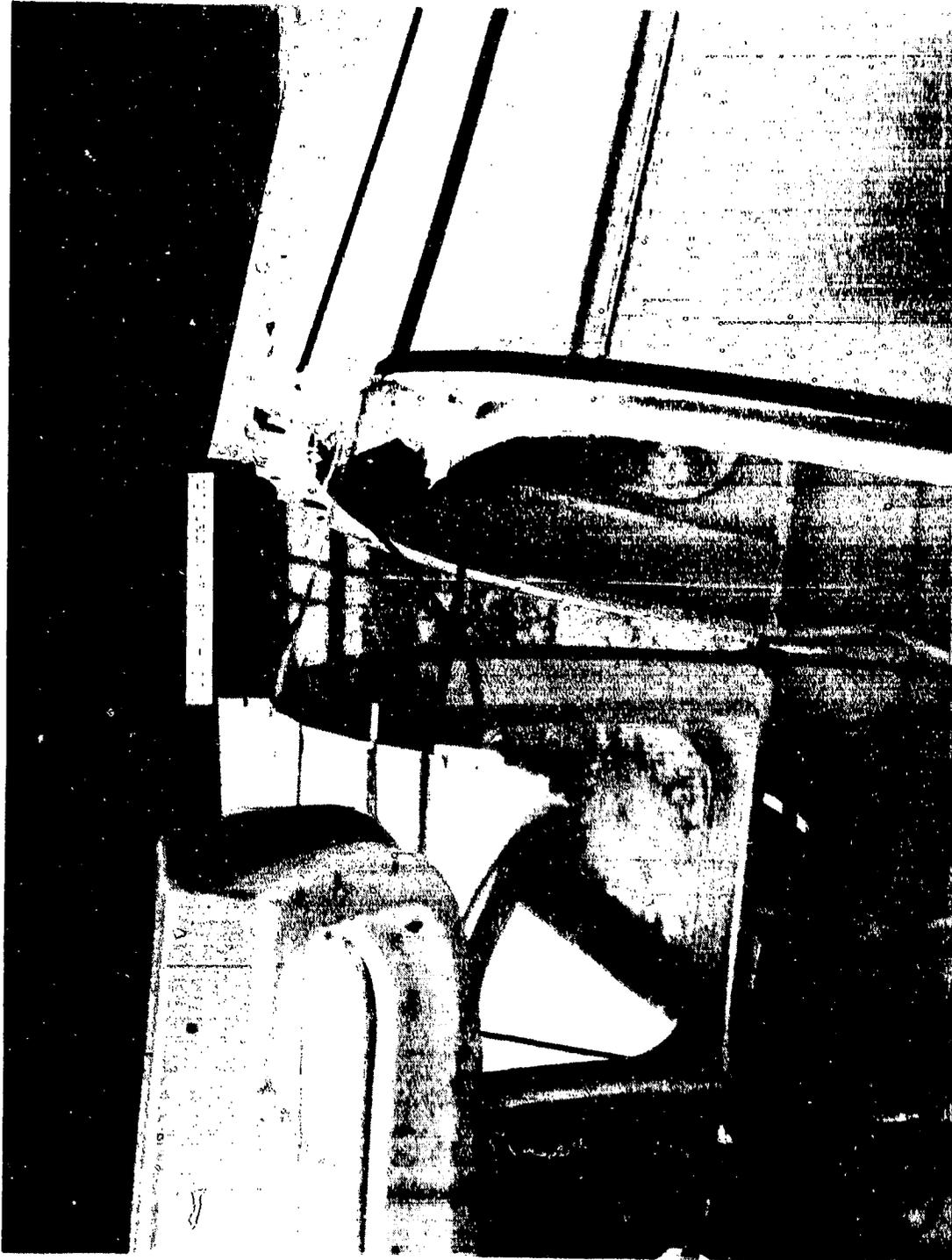
(e) NASA test 6 standard Navajo.

Figure 9.- Concluded.



(a) Chieftain.

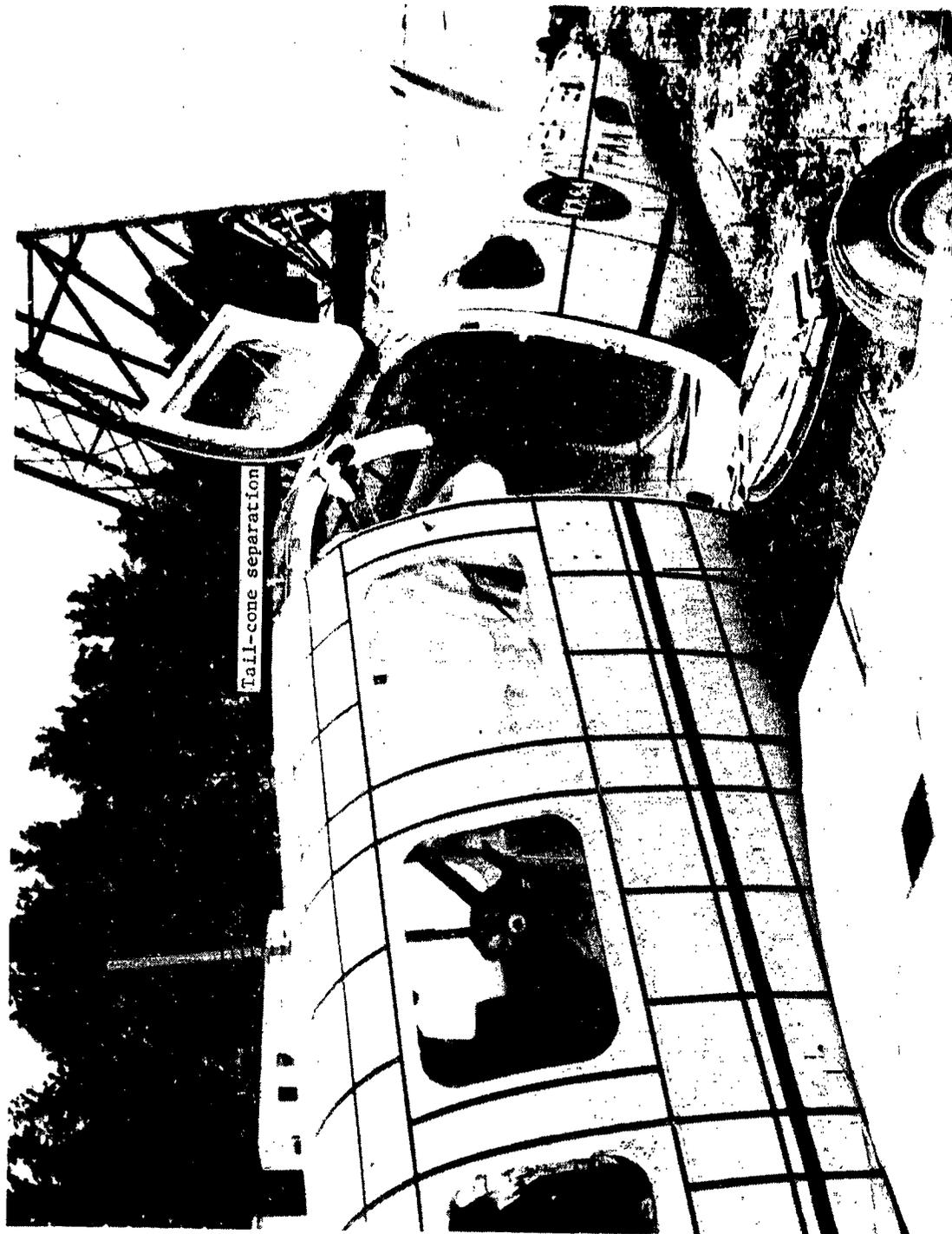
Figure 10.- Upper fuselage break at rear door of crashed airplanes.



L-76-4746.7

(b) NASA test 10 standard Navajo.

Figure 10.- Continued.



L-74-5482.1

(c) NASA test 3 standard Navajo.

Figure 10.- Concluded.



L-78-6724.1

Figure 11.- Cockpit floor and control tunnel damage of crashed Chieftain.

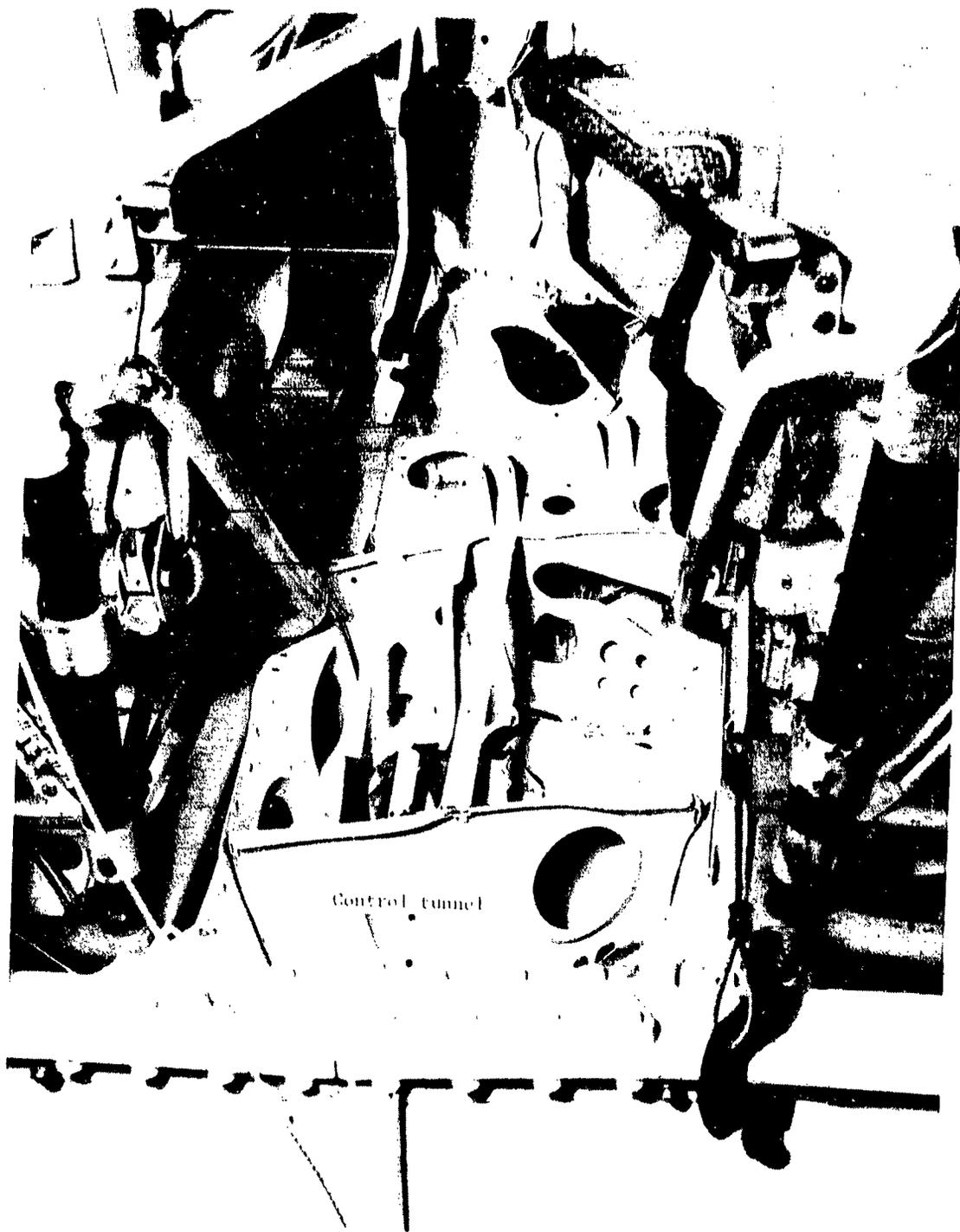
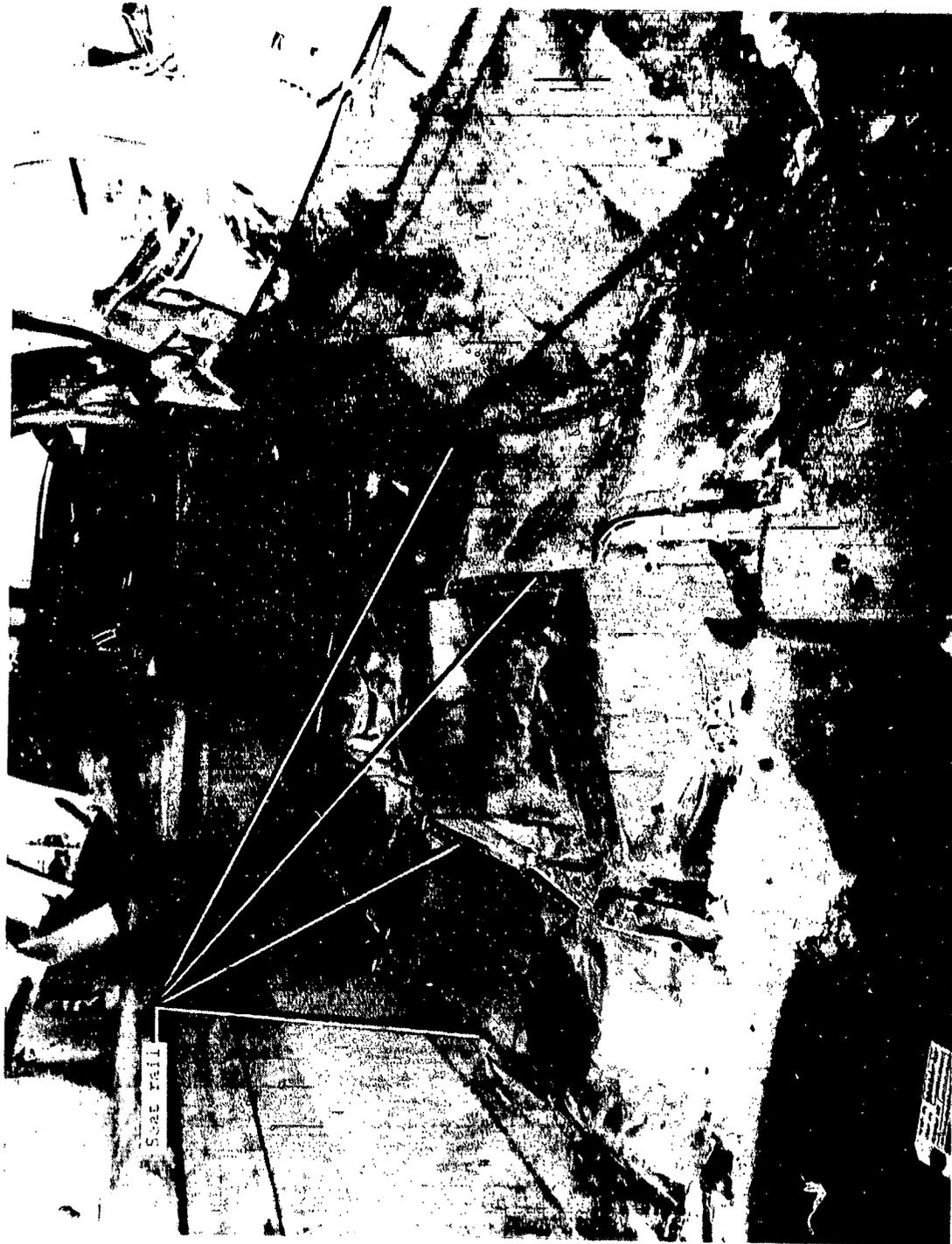


Figure 12.- Control-tunnel structural damage of NASA test 8 standard Navajo. L-75-9109.1



L-78-5142.7

(a) Cabin floor of crashed Chieftain after seat removal.

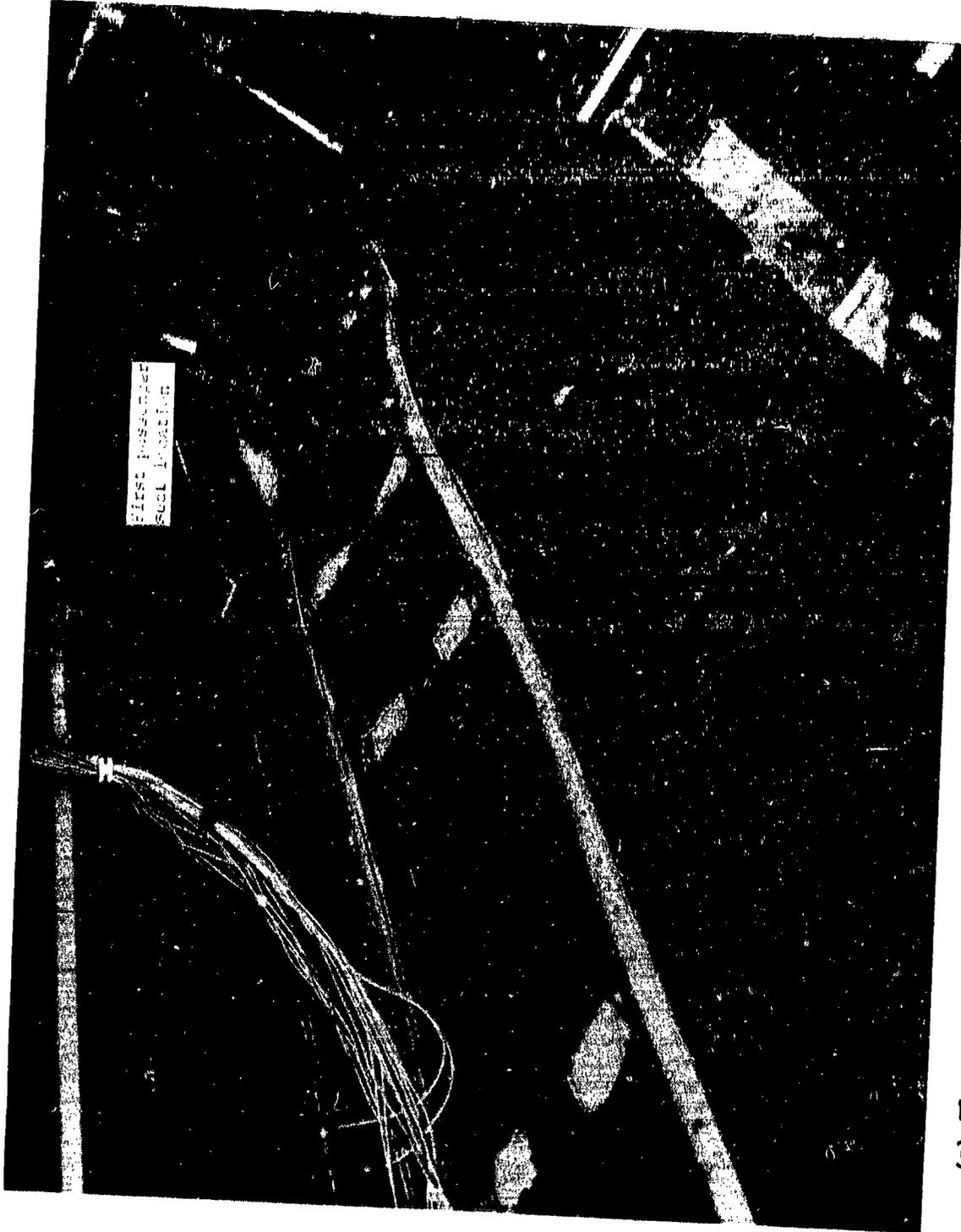
Figure 13.- Damage to cabin floors of crashed airplanes.



L-78-6113

(b) Cabin subfloor damage of crashed Chieftain.

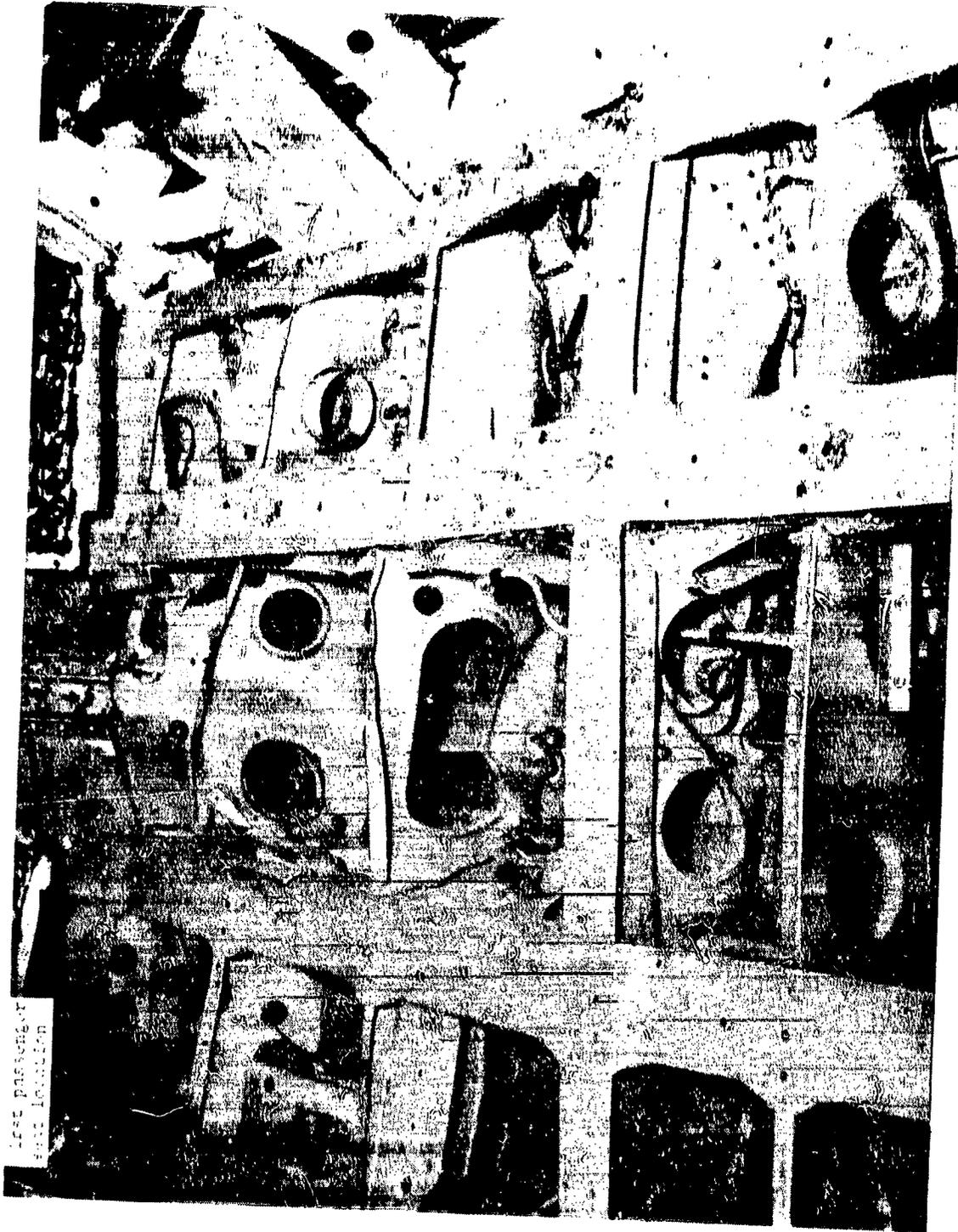
Figure 13.- Continued.



(c) Floor and rails at first passenger location of NASA test 7 standard Navajo. L-75-5600.7

Figure 13.- Continued.

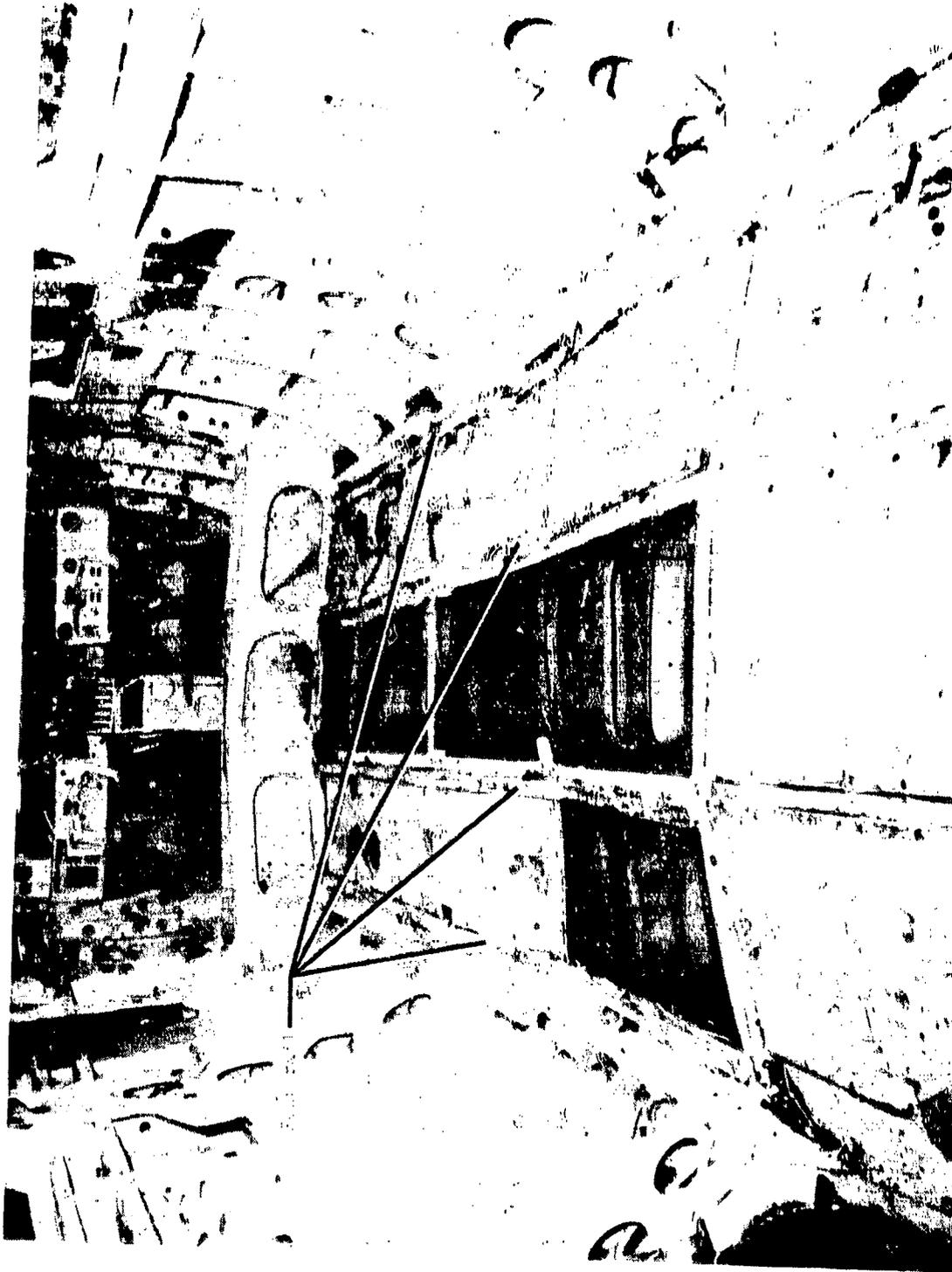
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L-75-6319.7

(d) Cabin subfloor damage of NASA test 7 standard Navajo.

Figure 13.- Continued.



L-74-6529.7

(e) Cabin floor and subfloor damage of NASA test 15 pressurized Navajo.

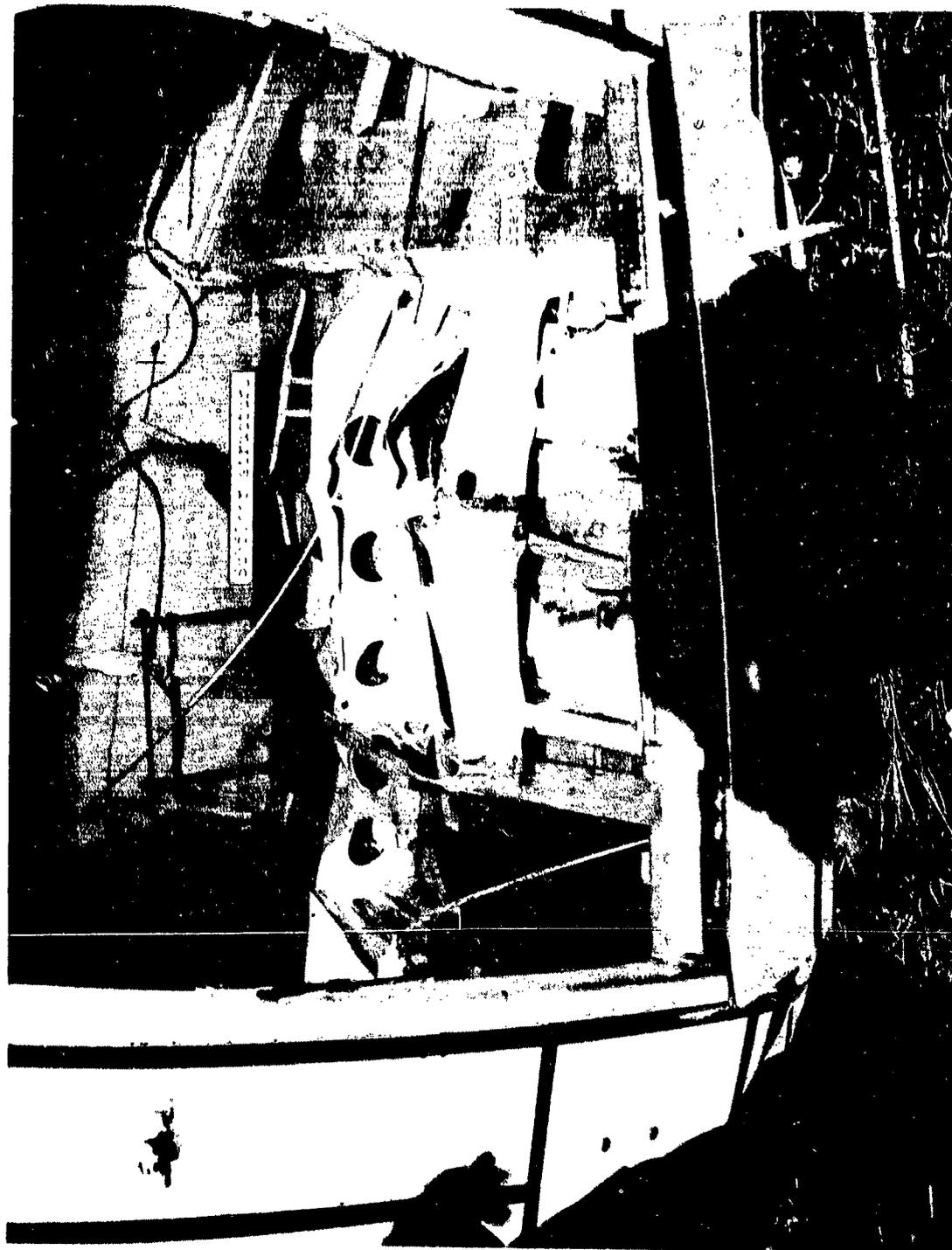
Figure 13.- Concluded.



I-78-6155.7

(a) Chieftain.

Figure 14.- View through rear doors of crashed airplanes.

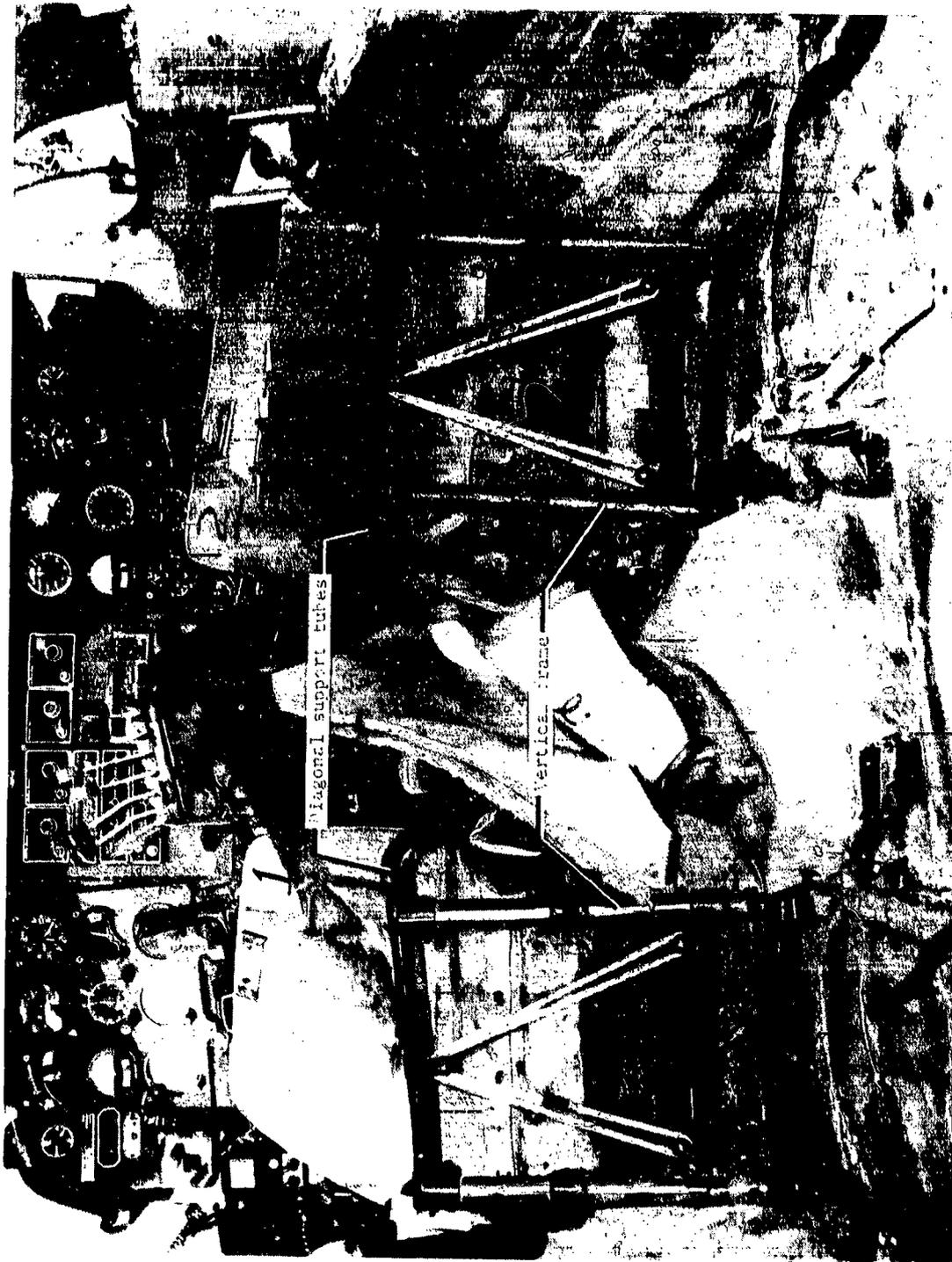


L-74-8077.7

(b) Subfloor of NASA test 4 standard Navajo.

Figure 14.- Concluded.

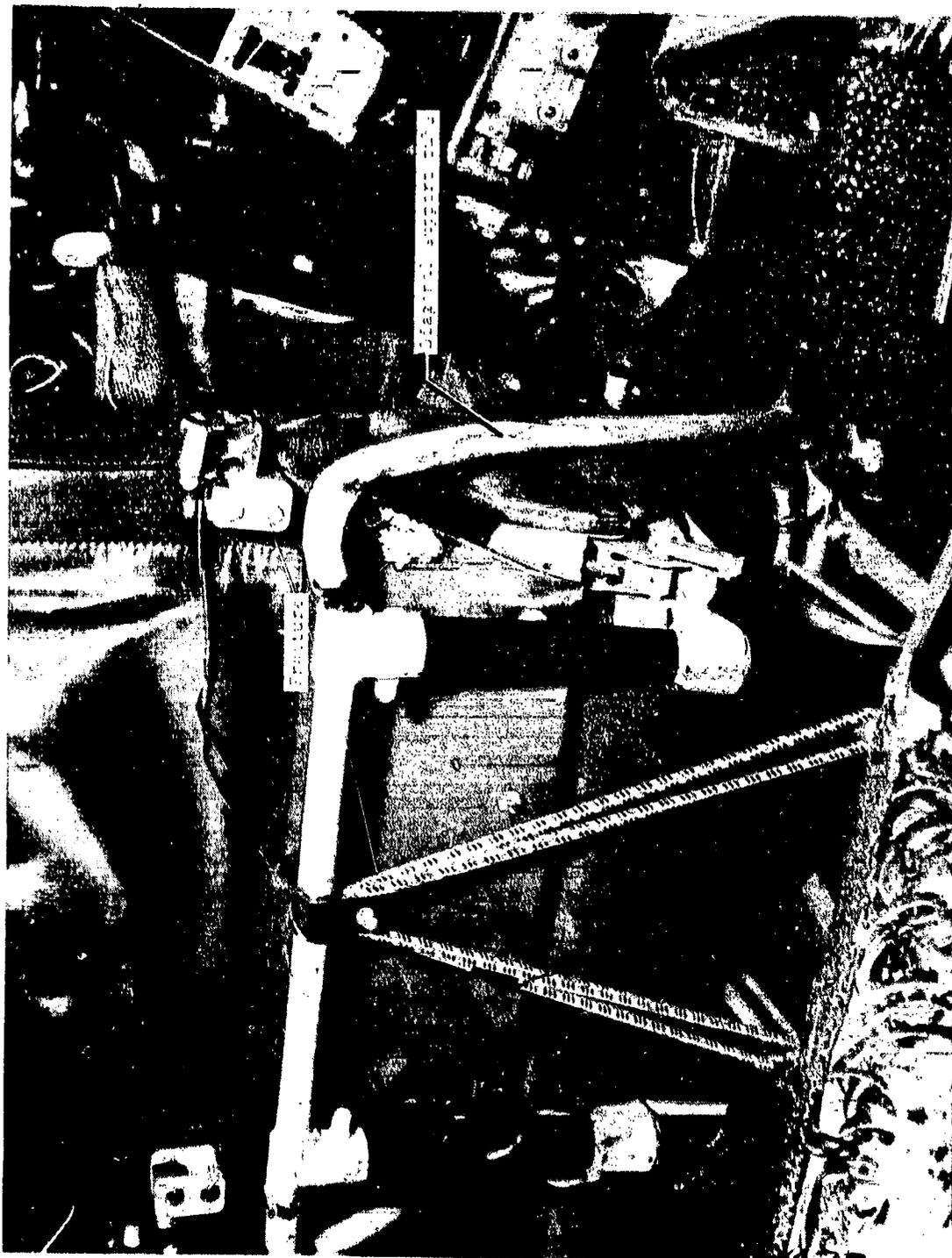
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L-78-6111.1

(a) Pilot and copilot seats of Chieftain.

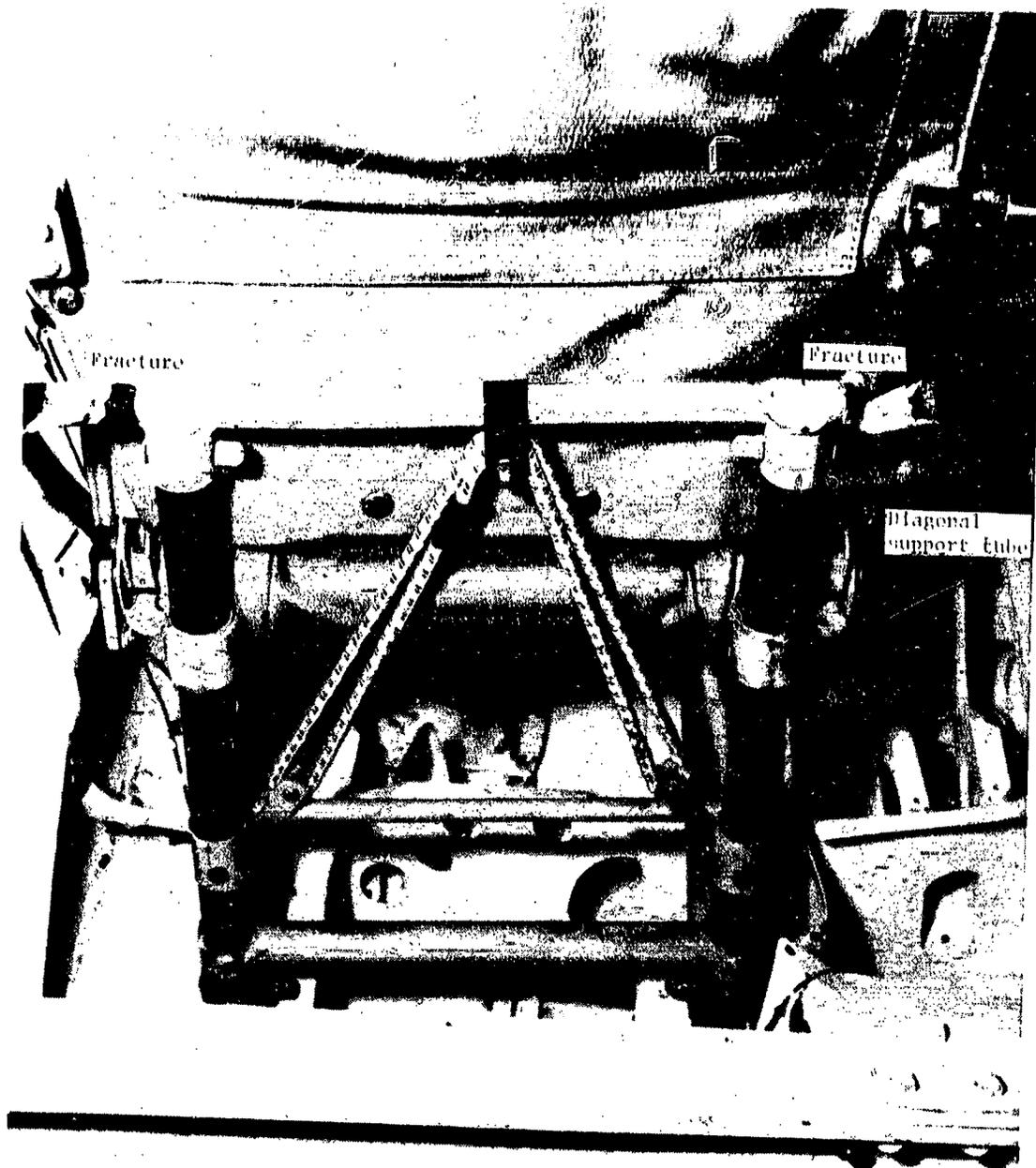
Figure 15.- Seats in cockpit of crashed airplanes.



L-75-6317.1

(b) Pilot seat of NASA test 7 standard Navajo.

Figure 15.- Continued.



(c) Pilot seat of NASA test 8 standard Navajo.

L-75-9094.1

Figure 15.- Concluded.



L-78-6153.1

(a) Passenger seats located on main spar.

Figure 16.- Damage to passenger seats and support of crashed Chieftain.

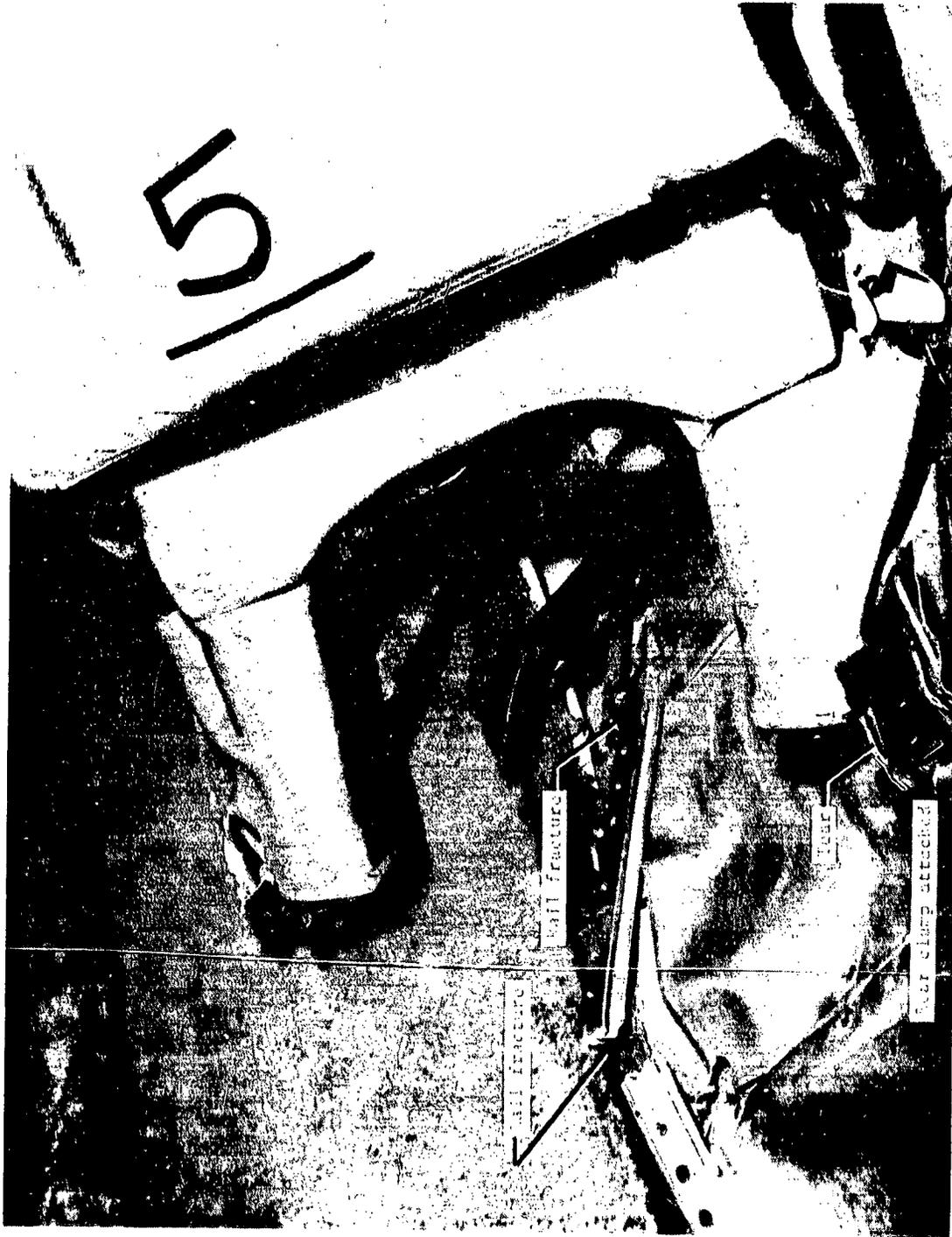


(b) Seat support structure and rails of passenger seat 4.

Figure 16.- Concluded.

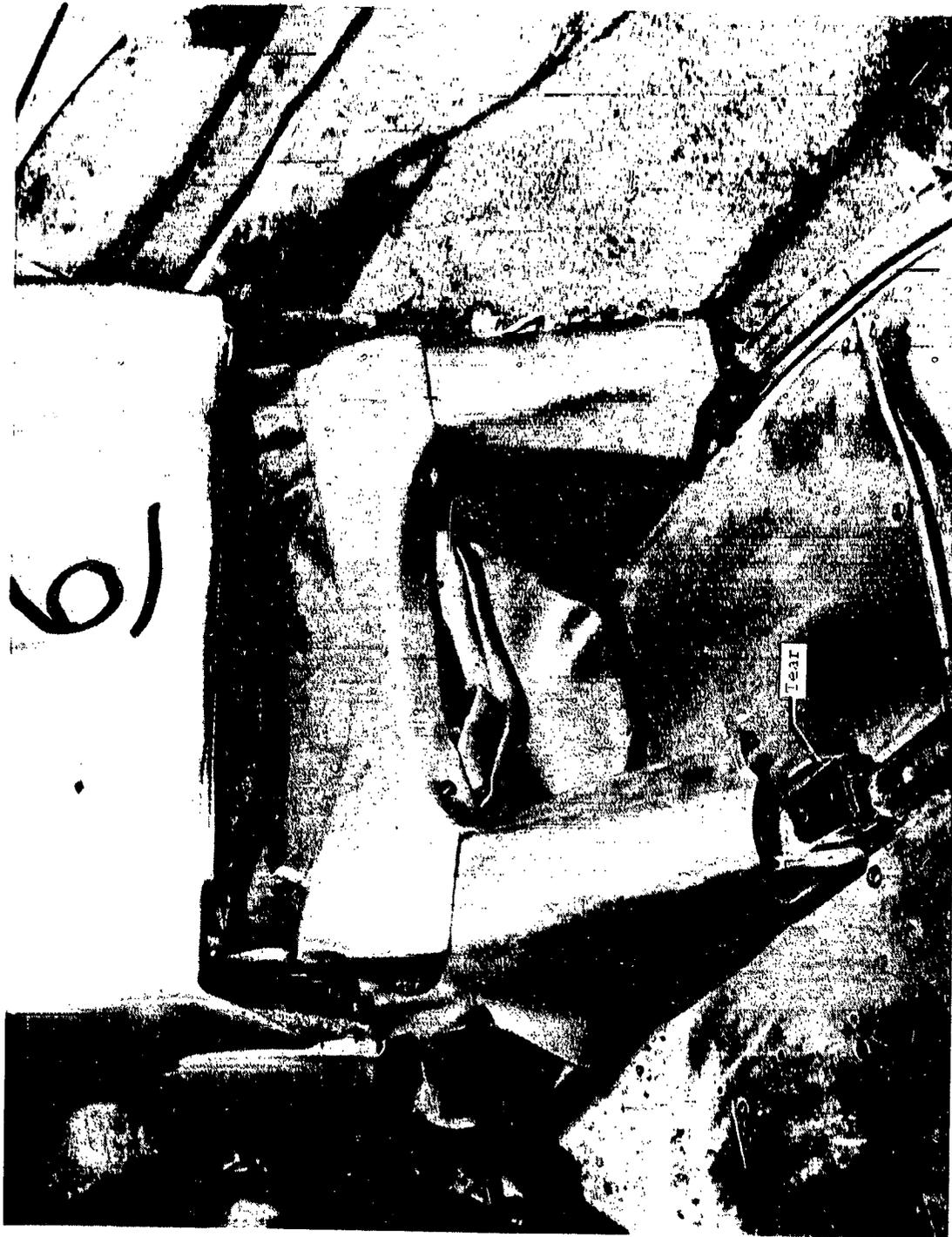


L-79-3074
Figure 17.- Hybrid II anthropomorphic dummy seated in standard
Navajo passenger seat.



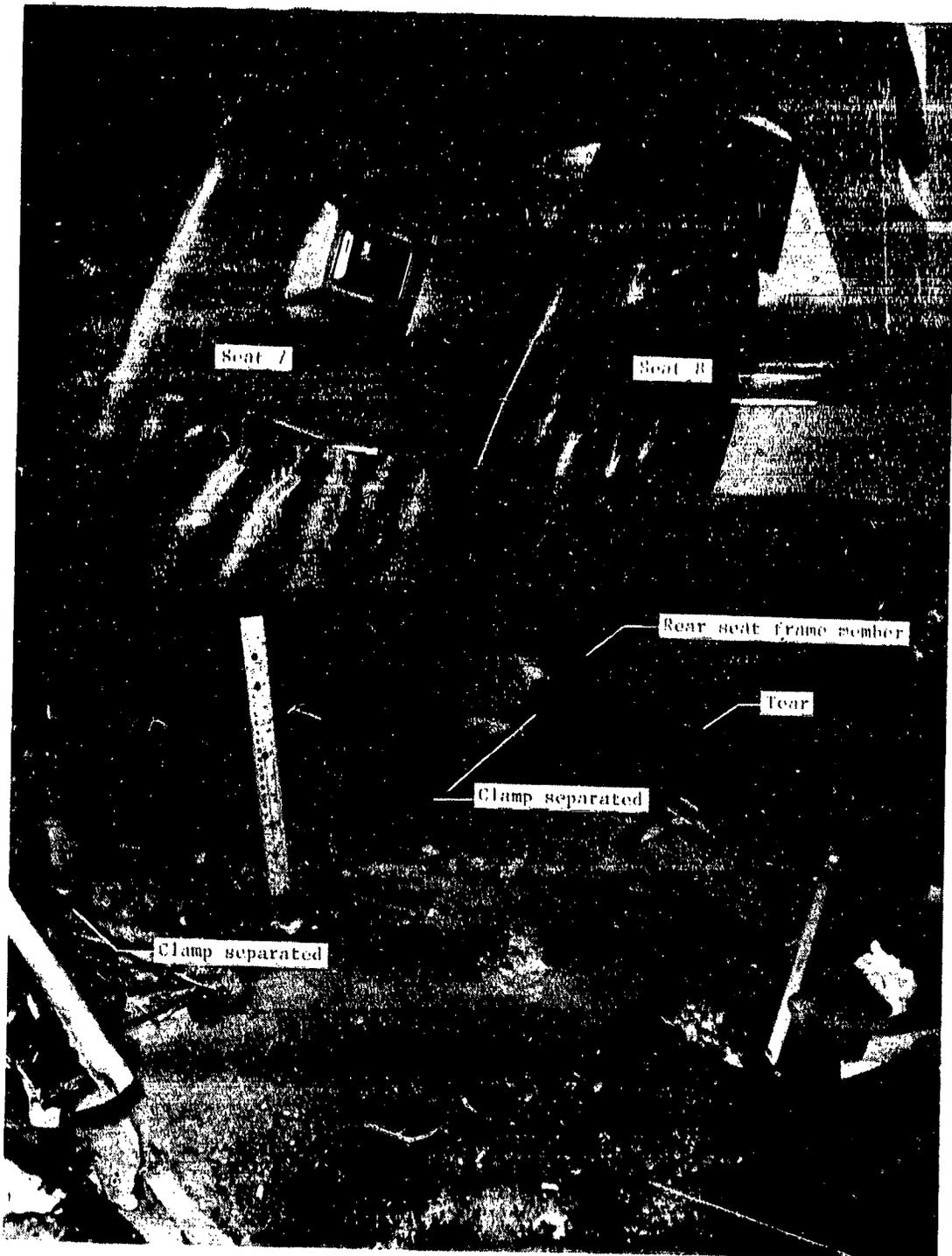
L-78-6744.7

Figure 18.- Seat 5 of crashed Chieftain.



L-78-6745.1

Figure 19.- Seat 6 of crashed Chieftain.



L-78-6156.1

(a) Seat 7 (left) and 8 (right) of crashed Chieftain.

Figure 20.- Passenger seats of crashed airplanes.



L-75-5642

(b) First passenger seat of NASA test 7 standard Navajo.

Figure 20.- Concluded.

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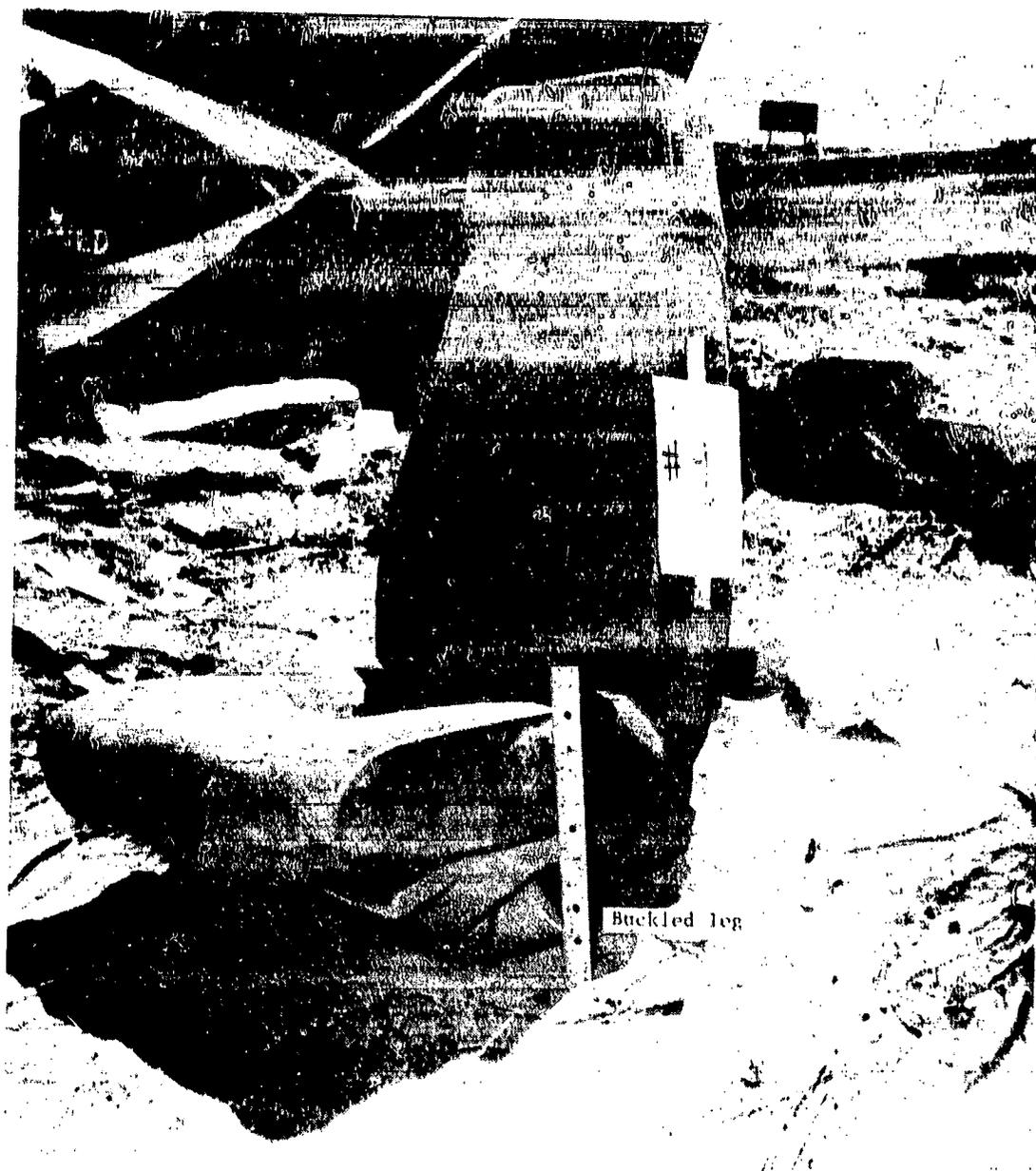


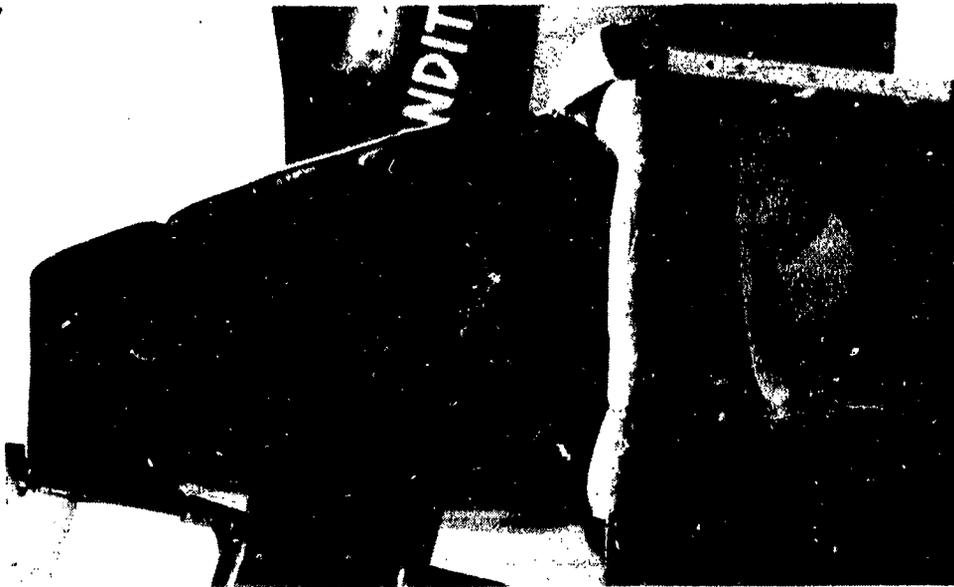
Figure 21.- Seat 9 of crashed Chieftain.

L-78-6159.1

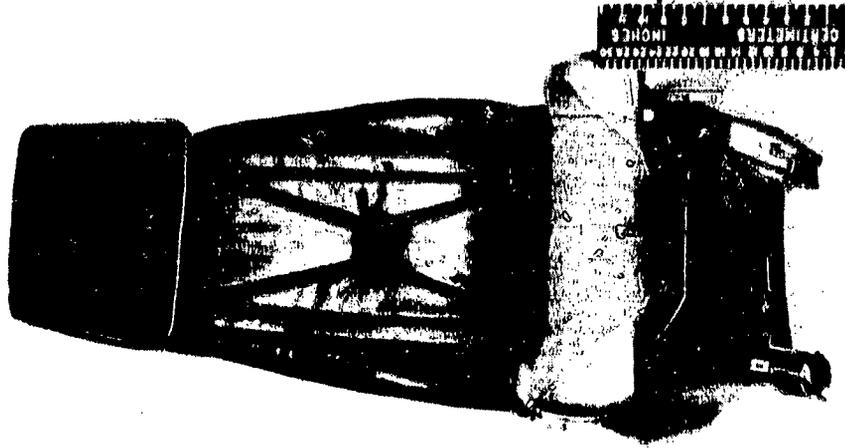


L-79-615B

Figure 22.- Seat 10 of crashed Chieftain.



71.7-kg (158-lb) passenger

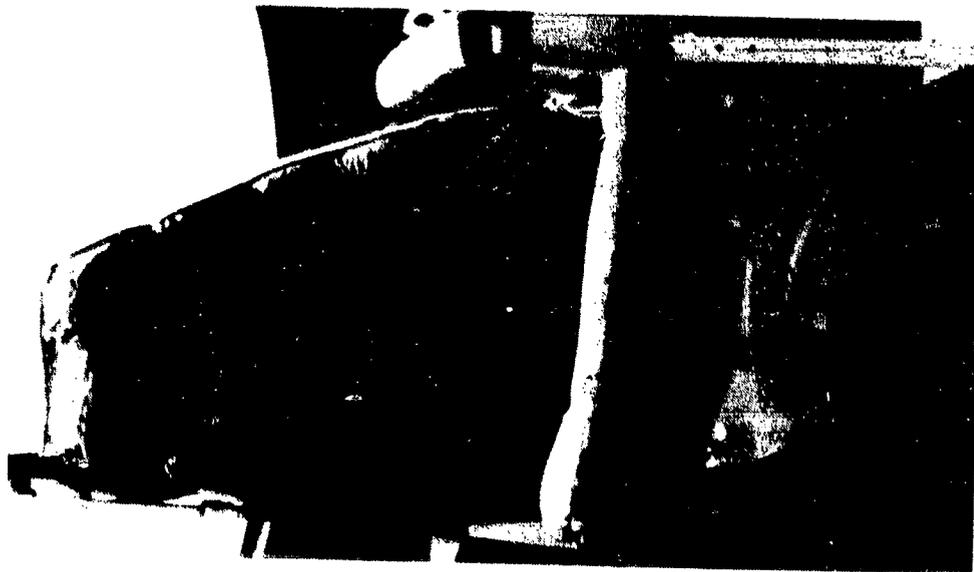


74.8-kg (165-lb) dummy

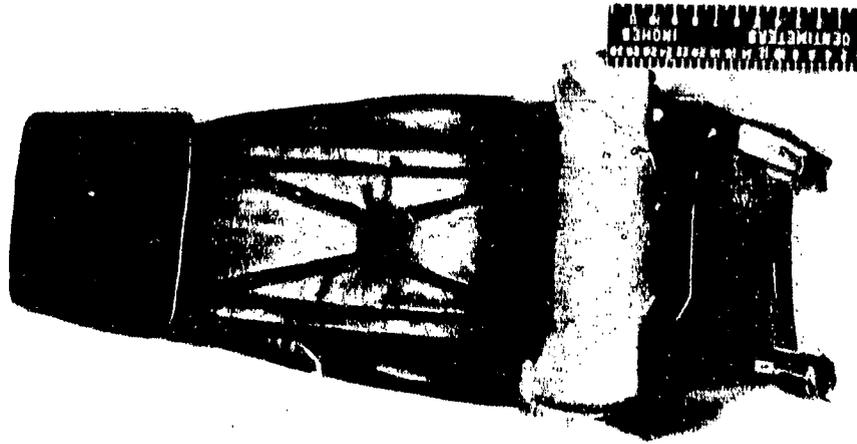
L-79-272

(a) Seat 6 from Chieftain and seat 3 from pressurized Navajo.

Figure 23.- Comparison of seats from Chieftain and NASA test 15 pressurized Navajo.



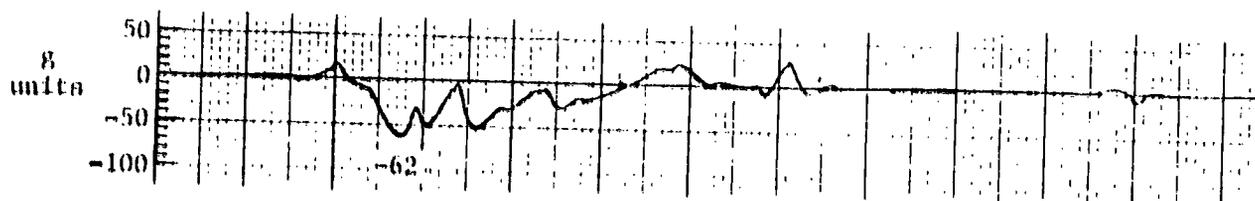
75.3-kg (166-lb) passenger



74.8-kg (165-lb) dummy

(b) Seat 8 from Chieftain and seat 3 from NASA test 15 pressurized Navajo. I-79-273

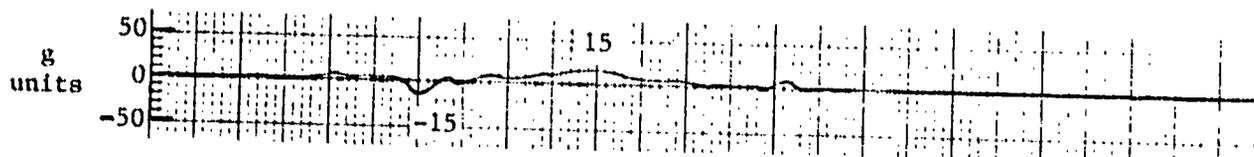
Figure 23.- Concluded.



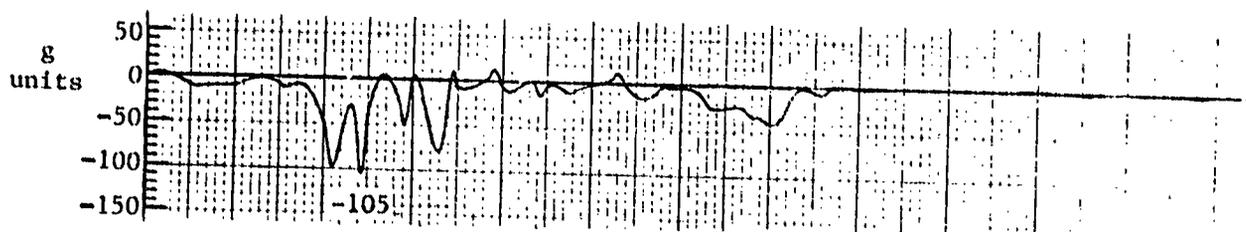
Pelvis normal (along spine)



Pelvis longitudinal (perpendicular to spine, fore and aft)



Pelvis transverse (perpendicular to spine, sideward)



Floor normal (near right front leg of seat)

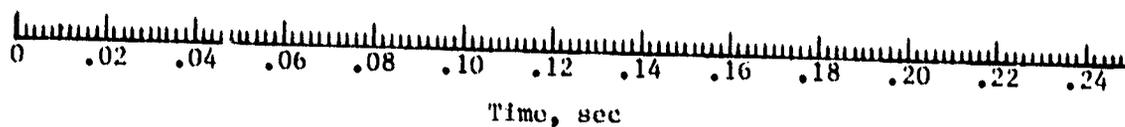


Figure 24.- Acceleration histories from first passenger and floor of NASA test 15. (dc accelerometers; data digitized and filtered with least-squares polynomial fit.)